UK-China Science Bridges:
R&D on (B)4G Wireless Mobile Communications

Work Package 1: Mission to China

Summary Report

December 2009

Project Website: http://uc4g.eps.hw.ac.uk

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Executive Summary

From 27 July to 7 Aug. 2009, the UK delegation of the UK-China Science Bridges Project in (B)4G Wireless Mobile Communications with 22 delegation members, led by Dr Cheng-Xiang Wang from Heriot-Watt University (HWU) and Dr Yang Yang from University College London (UCL), visited their 12 Chinese partners (7 universities and 5 companies) in 6 cities (Shanghai, Nanjing, Wuhan, Xi'an, Jinan, and Beijing). A welcome reception was hosted by British Consulate General Shanghai on 27 July 2009, attended by the Consulate representatives, a Scottish Development International (SDI) representative, UK delegation members, local Chinese partners, and Shanghai Government officials. Paul Wills, Consul of UK Trade and Investment (UKTI), chaired the reception and Jacqui Booker, Deputy Consul General of the British Consulate-General Shanghai, delivered a speech to kick off this project. A two-and-a-half day workshop was held at Tsinghua University, Beijing, from 4 to 6 Aug. 2009, with about 70 attendees. The workshop brought all the project consortium members together to present their research strengths in Wireless Communications and discuss future challenges and collaboration topics in 4G and beyond 4G (B4G). Prof. Yonghua Song (Assistant President of Tsinghua University), Mr Jijun Xing (Director of Europe, Department of International Collaboration, Ministry of Science and Technology), Mr Chris Godwin (Director of Research Councils UK (RCUK) China Office), and Mr Alastair Morgan (Commercial Counselor and Director of UKTI for China) all delivered welcome speeches to kick off the Beijing Workshop on 4 Aug. Dr Walter Tuttlebee from the Virtual Centre of Excellence in Mobile & Personal Communications (Mobile VCE), Prof. Joe McGeehan from the University of Bristol, Dr Shujun Dang from Huawei, and Prof. Ping Zhang from Beijing University of Posts and Telecommunications (BUPT) were invited to give keynote speeches introducing the latest development of Wireless Communications from academic and industrial perspectives in both the UK and China.

Thu UC4G Project and Consortium Members

The two-week visit is part of the first work package (WP) of the three-year project "UK-China Science Bridges: R&D on (B)4G Wireless Mobile Communications (UC4G)" funded by RCUK. The ultimate aim of this project is to create a UK-China Joint R&D Centre for Future Wireless Communication Networks. This remarkable project is unprecedented in terms of its scale and profile. It marks the start of UK-China long-term sustainable collaboration in wireless communications by supporting collaborative research, mutual visits, exchange of researchers, and rapid technology transfer and commercialisation. The project features a wide range of top UK-China experts and business leaders on (B)4G Wireless Mobile Communications, including 13 Chinese consortium members and 26 UK consortium members, both sides with world class research capabilities:

- 6 UK academic partners: HWU, University of Edinburgh, University of Bristol, University of Southampton, University of Bedfordshire, and UCL;
- 1 UK associate industrial partner: Mobile VCE (representing 15 companies);
- 4 UK associate academic partners: Kings College London (KCL), University of York, University of Strathclyde, and University of Surrey;
- 7 Chinese academic partners: BUPT, Huazhong University of Science & Technology (HUST), Shandong University (SDU), Shanghai Jiaotong University (SJTU), Southeast University (SEU), Tsinghua University (THU), and Xidian University (XDU);
- 6 Chinese industrial partners: Shanghai Research Centre for Wireless Communications (WiCO), Huawei Technologies Co., Ltd,, ZTE, China Mobile Communication Co., Jushri Wireless Technologies, Inc., and China Academy of Telecommunication Research (CATR).

Sponsors and Supporters for the Mission to China

In the UK delegation, 19 members were financially sponsored by the RCUK through the UC4G project, while the rest 3 members were sponsored by Digital Communications Knowledge Transfer Network (DC–KTN). The two-week visit was also generously supported by the RCUK China Office, British Embassy in Beijing, British Consulate General Shanghai, Ministry of Science and Technology (MOST) of China, National Natural Science Foundation of China (NSFC), Science & Technology Commission of Shanghai Municipality, and all of our 13 Chinese partners.

Outcomes

The mission to China has successfully achieved the predefined aims and produced fruitful outcomes.

- The UC4G project has been further promoted. The huge potential and value of the UK-China collaboration has been widely recognised, confirmed, and appreciated by not only all the UK and Chinese consortium members but also various governmental bodies from both sides.
- All the consortium members have become familiar with each other, which will greatly facilitate broadening and strengthening collaboration links. Complementary strengths in (B)4G R&D activities have been identified. Suggested topics for future collaboration and how to effectively run WP2 (supporting 30 exchange researchers for up to 3 months) of the UC4G project were openly discussed.
- How to enhance the impact of the project was discussed, such as taking the opportunity of Expo Shanghai 2010 to organise the first workshop for WP3 and showcase the UC4G project.
- How to secure further (joint) funding from e.g., Engineering and Physical Sciences Research Council (EPSRC) and Technology Strategy Board (TSB) in the UK, MOST and NSFC in China, European Union (EU), and industries was discussed in order to support the project, especially for WP4 prototype/testbed development and WP5 Commercialisation, and support long-term sustainable UK-China collaboration beyond the project period.
- Substantial attention has been attracted at the government level from both the UK and China sides. Invited officials from the British Embassy, MOST, and NSFC have all indicated the possibility and willingness of providing further supports to sustain, reinforce, and expand the existing UK-China collaboration network.
- Wider awareness of the UC4G project has been raised. Researchers from several organisations, such as National Physical Laboratory (UK), Swansea University, University of Essex, Aeroflex Cambridge Ltd., Nokia Siemens Networks (Beijing), Peking University, and Zhejiang University, have been attracted to participate in part or all of the visiting activities in China and have all expressed their strong wishes to join the UK-China collaboration network.

Key Findings

China has a national strategy to become a major player in the (B)4G area. The Chinese government appears to have a clear vision in making strategic investments to achieve world-class R&D capabilities in the (B)4G sector. These government investments are strongly focused on key research programmes, key laboratories, and top universities. The funding structure ensures that the high-level government vision can be effectively implemented in a top-down fashion. All the UK delegation members have been impressed by China's rapid growth after the visit to our Chinese partners. There have been discussions regarding how to deepen and strengthen the collaboration by securing further funding, especially the funding to UK universities from the UK government, so that the UK does not fall behind.

- Key Chinese universities and research institutions have been receiving strong support from the government and industry to the 3G/(B)4G R&D. There is a significant funding gap between the UK and China in Wireless Communications area. The funding received by a major Chinese research group can be easily ten times larger than the funding received by a UK research group.
- Major research groups in Chinese top universities are much larger than those in the UK. This allows Chinese research groups to cover a wider range of (B)4G research topics. The top-down administration structure in Chinese research groups makes the collaboration among all the group members much closer.
- With a large amount of funding and less funding overhead and staff costs, major Chinese universities are able to effectively use the funding to support infrastructure development and employ more research staff and students. Consequently, all of our Chinese academic partners have been not only able to conduct good-quality research but also heavily involved in the prototype/testbed development of 3G/(B)4G systems. Their R&D outcomes cover not only research papers, but also patents and standardisation proposals.

- Large numbers of Chinese researchers who had experience in studying and/or working abroad had returned China with leading positions in universities/industries. This has greatly improved the R&D quality, communication ability in English, and visibility of relevant Chinese universities/industries.
- Major Chinese Telecom companies have expanded their overseas business rapidly and are becoming more and more active in all kinds of global standardisation activities.
- The Chinese government is very ambitious to make China a major player in global (B)4G standardisation. The central government has revealed a plan to invest 70 billion RMB (1 GBP ≈ 10 RMB) on new generation mobile wireless broadband communication networks in the period from 2008 to 2020. Huge funding to the wireless communications sector is also available from the provincial or municipal governments.
- Compared to China, the strength of the UK comes from the very productive research system. The wireless communication research community in the UK has been very active and taking a leading position in the global (B)4G R&D activities. The original research ideas and fundamental contributions from the UK academics have been published and cited frequently in leading international journals and conference proceedings. The unique linkage between the academia and industry, such as that created by the Mobile VCE, continues to offer very high returns for R&D investment.

Summary

It is the complementary strengths of the UK and China that make a joint collaboration initiative necessary and extremely valuable. Although substantive existing collaborative activities between the UK and China are evident, they are mostly independent and uncoordinated implemented by individual researchers. To harness the full potential and generate greater impacts of the UK-China collaboration, it is crucial and timely to promote this systematic, long-term, and sustainable joint research initiative between the UK and China in wireless communications.

This UC4G project carries the expectation of both the UK and China to join hands to win "the global race to the top" of the Information and Communication Technology (ICT) sector. In Jacqui's speech in the welcome reception on 27 July 2009, she remarked: "we are fortunate enough to witness the kick-off of this RCUK Science Bridges project. It is another significant move towards an innovation-driven UK-China collaboration in 4G Wireless Mobile Communications… We do hope that both UK and Chinese businesses can reap the economic and environmental benefits arising from this research partnership." In Alastair's welcome speech at the Beijing Workshop on 4 Aug. 2009, he remarked: "I believe this UK-China Science Bridge will certainly accelerate knowledge transfer and commercialisation and impact the international standardisation process of 4G wireless mobile communications… We are confident that this year, we will be seeing more Chinese ICT companies choosing UK as the ideal place for them to launch their international ambitions. And many more UK companies win business in China through Science bridge projects, through Enabling Innovation initiative, and through many more other government funded programmes".

Acknowledgments

The UK delegation members would like to thank the Research Council UK (RCUK) for sponsoring this visit. We are also very grateful to the British Embassy in Beijing, the British Consulate General Shanghai (BCGS), Digital Communications Knowledge Transfer Network (DC–KTN), the Ministry of Science and Technology (MOST) of China, the National Natural Science Foundation of China (NSFC), and the Science & Technology Commission of Shanghai Municipality (STCSM), for their generous supports.

We would also like to express our gratitude to the Chinese universities, research institutions, and companies we visited, for their extremely warm receptions and hospitability. Special thanks must be given to Tsinghua University, for the excellent organisation of the Beijing workshop. Our appreciation also goes to many of our UK and Chinese friends and colleagues, who kindly helped us plan the travel itinerary, arrange local accommodation and visiting activities, establish new connections, etc. Specifically, we would like to thank the following people (in alphabetic order by affiliation names):

Aeroflex
Dr. Li-Ke Huang
Univ. of Bedfordshire
Prof. Jie Zhang
Univ. of Bristol
Prof. Joseph P. Mcgeehan
Prof. Mark A. Beach
Prof. Siyuan Yu
British Telecom
Dr. Xuanye Gu (BT, UK)
Dr. Jie Zhang (BT, Beijing)
Dr. Quan Li (BT, Beijing)
BCGS
Ms. Jacqui Booker
Mr. Paul Weills
Ms. Lily Zhu
Ms. Vivan Liu
Ms. Amy Zhang
BUPT
Prof. Xiaomin Ren
Ms. Chunxia Ren
Ms. Xinying Tang
Prof. Ping Zhang
Prof. Xiaofeng Tao
Dr. Qimei Cui
Dr. Guixia Kang
Dr. Xiaodong Xu
Dr. Qiang Wang
Dr. Yuexia Zhang
China Mobile
Dr. Xiaoqing Huang
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Dr. X. Li
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Mr. Weihui Dong
Ms. Xing Chen
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Ms. Wei Li
Dr. Bo Li
Dr. Peng He
Dr. Dongyi Zhou
Ms. Lei Wen
Dr. Peng He
Dr. Dongyi Zou
Mr. Xiang Wu
CATR
Mr. Zhiyong Liu
Ms. Xiaoli Ma
Mr. Kun Wang
Dr. Peng Yang
Univ. of Edinburgh
Prof. Peter Grant
Dr. Harald Hass
Univ. of Essex
Dr. Kun Yang
Huawei
Mr. Jun Shu
Mr. Tao Ma
Mr. Gong (Nicholas) Zhang
Dr. Lingqi Li
Dr Ying Gong
Dr. Shujun Dang
Dr. Yi Wang
Dr. Shugong Xu
Dr. Feng Liu
Dr. Xuezhi Yang
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Nokia-Siemens Networks
Dr. Hao Guan
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NSFC
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ZTE
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Dr. Guang Yang

Abbreviations

863	Hi-Tech Research and Development Programme of China
973	National Basic Research Programme of China
2G	the Second Generation
3G	the Third Generation
4G	the Fourth Generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
AMC	Adaptive Modulation and Coding
ASIC	Application-Specific Integrated Circuit,
B3G	Beyond Third Generation
B4G	Beyond Fourth Generation
BS	Base Station
BT	British Telecommunications plc.
BUPT	Beijing University of Posts and Telecommunications
CATR	China Academy of Telecommunications Research
CEO	Chief Executive Officer
CLD	Cross-Layer Design
CMRI	China Mobile Research Institute
CoMP	Coordinated Multi-Point
CPM	Continuous Phase Modulation
CR	Cognitive Radio
CTR	Centre for Telecommunication Research
CTTL	China Telecommunication Technology Lab
CWiND	Centre for Wireless Network Design
D2D	Device to Device
DAS	Distributed Antenna System
DC–KTN	Digital Communications Knowledge Transfer Network
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EPSRC	Engineering and Physical Sciences Research Council
FDD	Frequency Division Duplex
FDTD	Finite Difference Time Domain
FREng	Fellow of the Royal Academy of Engineering
FuTURE	Future Technologies for Ubiquitous Radio Environment
GR	Green Radio
GSM	Global System for Mobile Communications
Huawei	Huawei Technologies Co. Ltd.
HUST	Huazhong University of Science and Technology
HWU	Heriot-Watt University
KCL	King's College London
ICT	Information and Communication Technology
IDMA	Interleave Division Multiple Access
IDCOM	Institute for Digital Communications
IET	The Institution of Engineering and Technology
IEEE	Institute of Electrical and Electronics Engineers
IMC	Interference Modelling and Coordination
IMT	International Mobile Telecommunications
ITU	International Telecommunication Union
IP	Internet Protocol
IPR	Intellectual Property Right
JRI-SIP	Joint Research Institute for Signal and Image Processing
LSE	London School of Economics and Political Science
LTE	Long term evolution
MA	Multiple Access
MAC	Medium Access Control
MII	Ministry of Information Industry
MIIT	Ministry of Industry and Information Technology
MIMO	Multiple Input Multiple Output
Mobile VCE	Virtual Centre of Excellence in Mobile and Personal Communications
MOST	Ministry of Science and Technology

M-RAT	Multiple Radio Access Technology
NGWNet	Next Generation Wireless Communications Network
NPL	National Physical Laboratory
NSFC	National Natural Science Foundation of China
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
QAM	Quadrate Amplitude Modulation
QoS	Quality of Service
PAPR	Peak-to-Average Power Ratio
PMP	Point to Multi-Point
PI	Principal Investigator
RAT	Radio Access Technology
R&D	Research and Development
RF	Radio Frequency
RFID	Radio Frequency Identification
RRM	Radio Resource Management
SDI	Scottish Development International
SDU	Shangdong University
SDR	Software Defined Radio
SEU	Southeast University
SIMIT	Shanghai Institute of Microsystem and Information Technology
SIR	Signal-to-Interference Ratio
SISO	Single-Input Single-Output
SJTU	Shanghai Jiaotong University
SNR	Signal-to-Noise Ratio
SON	Self Organising Network
STCSM	Science & Technology Commission of Shanghai Municipality
TD-CDMA	Time Division – Code Division Multiple Access
TDD	Time Division Duplex
TD-LTE	Time Division – Long Term Evolution
TDMA	Time Division Multiple Access

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1. Introduction

1.1. 4G and B4G Overview

In a world of increasing mobility, wireless mobile communications play an indispensable role to satisfy the growing need for people to stay connected and have timely access to information regardless of their locations. The phenomenal success of wireless mobile communications is mirrored by a rapid pace of technology innovation. From the second generation (2G) mobile communication systems debuted in 1991 to the third generation (3G) systems first launched in 2001, the wireless mobile network has transformed from a pure telephony system to a network that can transport rich multimedia contents. Over recent years, tremendous Internet proliferation on the fixed broadband network has urged users to demand ubiquitous mobile broadband connectivity. The increasing demand of mobile broadband requires an upgrade of the 3G system to provide a much higher transmission speed and larger network capacity. To meet this demand, intensive research and development (R&D) activities have been undertaken around the globe to drive migrations toward the 4th generation (4G) mobile network.

The International Telecommunication Union (ITU) is in charge of coordinating efforts of the governments, industry, and private sectors to develop international mobile communication standards. The ITU is currently developing standards for the International Mobile Telecommunications-Advanced (IMT-Advanced) [1] systems, which are widely regarded as 4G networks. IMT-advanced is defined as [2]:

> "*Systems beyond IMT-2000, for which there may be a need for a new wireless access technology to be developed around the year 2010, capable of supporting high data rates with high mobility. High mobility here covers high speed on highways or fast trains (60km/h to 250km/h, or more.) It is predicted that potential new radio interfaces will need to support data rates of up to approximately 100Mbps for high mobility such as mobile access and up to approximately 1Gbps for low mobility such as nomadic/local wireless access, by around the year 2010.*"

In addition, the IMT-Advanced systems should have the following characteristics [2]: (1) High degree of commonality of design worldwide; (2) Compatibility of services within IMT-Advanced and with the fixed networks; (3) High quality; (4) Small terminal suitable for worldwide use; (5) Worldwide roaming capability; (6) Capability for multimedia applications within a wide range of services and terminals. Open call for proposals of the IMT-Advanced systems is expected to be closed at the end of 2009. The deployment of such systems may begin as early as 2012. Major candidates for the 4G standards include the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE)-Advanced [3], mobile WiMax [4], and the 3GPP2 Ultra Mobile Broadband (UMB) [5]. Figure 1 illustrates the evolution roadmap of these three mobile broadband technologies [6].

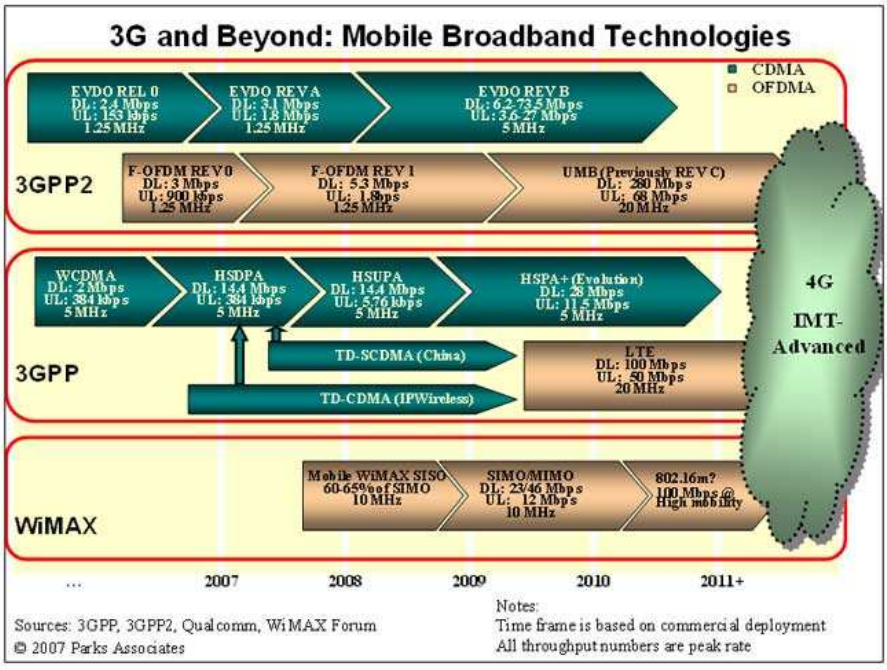


Figure 1. Evolution of mobile broadband technologies towards 4G/IMT-Advanced [6].

Technological innovation for 4G systems has been very active due to the potentially very high financial returns. According to the current consensus, 4G will provide advanced radio interface featured with orthogonal-frequency-division-multiplexing (OFDM), multiple-input multiple-output (MIMO), and link adaptation technologies. Regarding the system architecture, 4G systems will start to integrate heterogeneous wireless networks into an all-IP based 4G network. Many other advanced technical concepts, such as software defined radio (SDR), cooperative communication, cognitive radio, multi-cell processing, cross-layer optimization, policy-based network management, self-optimising network (SON), and green radio have been proposed for 4G and beyond 4G (B4G) wireless networks. It is widely believed that substantial R&D work is still required to validate these advanced technical concepts in practical mobile communication networks. However, some early-stage implementation of these concepts, such as software-define radio and cooperative communications, may start to be seen in 4G networks. More importantly, these advanced concepts exemplify the long-term potential and prospects of future wireless communication systems. Besides the ongoing endeavours to standardise and develop 4G systems, researchers around the globe have started B4G R&D.

1.2. (B)4G R&D in the UK and China

The UK's R&D strength in mobile communications is showcased by the Virtual Centre of Excellence in Mobile and Personal Communications (Mobile VCE), comprising 6 academic members[1], 6 associate academic members[2], and 15 industrial members[3] [7]. Mobile VCE was established in 1996 and jointly funded by its industrial members and the UK government as a non-profit organisation, aiming at facilitating leading edge R&D that is industry-led, globally relevant, long-term, and world class in mobile communications. Its main activity is to conduct programmes of core research—a substantial portfolio of typically three or four research streams defined by its industry members. The evolution track of Mobile VCE's core research programmes is illustrated in Figure 2 [7]. Recently, Mobile VCE has successfully completed four core research programmes and has entered Core 5, which compromises four work areas: (1) Flexible networks; (2) Green radio; (3) User interaction; and (4) Security-instant knowledge. Notably, the concept of 'green radio' was coined by the Mobile VCE in the Core 5 programme and has since then been adopted world-wide and inspired a thriving new research trend of energy-efficient wireless mobile networks. Over the past 13 years, Mobile VCE has developed and refined highly effective methods and mechanisms for academic-industry interaction and research management, which have contributed to its last two core programmes being ranked by independent assessments as having Research Quality that is 'Internationally Leading' and an Overall Performance of 'Outstanding'. The success of Mobile VCE plays an essential role in maintaining UK's leading position in 4G & B4G wireless communications.

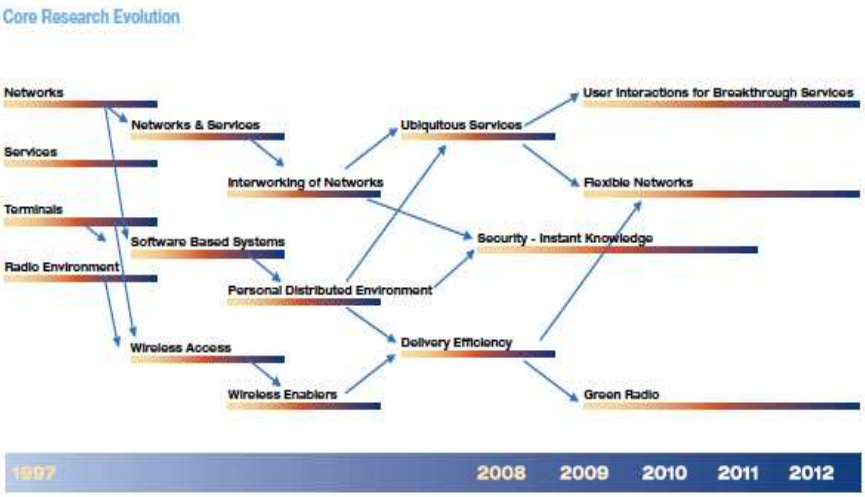


Figure 2. Evolution of core research programmes of Mobile VCE [7].

[1] University of Bristol, University of Edinburgh, King's College London, University of Southampton, University of Strathclyde, University of Surrey.
[2] University of Bath, University of Glasgow, Imperial College London, London School of Economics and Political Science (LSE), Royal Holoway, Swansea University
[3] Alcatel-Lucent, BBC, BT, Fujitsu, Huawei Technologies, Hutchison 3G, NEC, Nokia Siemens Networks, Nortel, Orange Labs, Samsung, Thales, Toshiba, Turner, Vodafone.

China is an ambitious and increasingly significant country in wireless communications. Having the world's largest mobile subscriber population, the number of mobile subscribers in China reached 700M in the first half of 2009, with a penetration rate of about 52.5%. The huge market potential urges China to develop its own intellectual properties (IPs) to better benefit from its booming mobile communication sector and offers China tremendous opportunity to influence the international standardisations of 3G, 4G, and even B4G systems. The growing influence of China was first clearly shown in 3G R&D, where China has successfully promoted its home-grown 3G standard – time-division synchronous code-division multiple access (TD-SCDMA). Entering the 4G era, China appears to have an ambitious plan to further raise its global profile and has given very strong supports to (B)4G R&D activities in China through the National High-Tech 863 Programme. The most influential (B)4G R&D element undertaking in China is the Future Technologies for Universal Radio Environment (FuTURE) project, which brings together the best researchers and industrialists in China, aiming at supporting theoretical research and testbed development of beyond 3G (B3G) mobile communications technologies. The FuTURE project has successfully completed the first phase and has entered the second phase (2006–2010), where the focus is on conducting trials of pre-commercial 4G systems. Recently, the central government has revealed another long-term plan to invest 70 billion RMB on new generation mobile wireless broadband communication networks in the period from 2008 to 2020. Typically, the government funding is strongly focused on key research programmes, key laboratories, and top universities. The funding structure ensures that the high-level government vision can be effectively implemented in a top-down fashion. With a large amount of funding and less funding overhead and staff costs, major Chinese universities are able to effectively use the funding to not only conduct good-quality research but also heavily involved in the prototype/testbed development of 3G/(B)4G systems. Their R&D outcomes cover not only research papers, but also patents and standardisation proposals. Major telecom companies in China, such as China Mobile, Huawei, and ZTE, have grown very quickly and successfully expanded to overseas markets.

It has been recognized for years that the UK and China have complementary strengths is the area of (B)4G R&D [8]. This complementarity creates excellent collaboration opportunities between the UK and China. Such collaborations can be very beneficial for both countries to sustain and/or raise their profiles and global influences in future wireless mobile communication systems. Although substantive ongoing and past collaborative activities between the UK and China are evident [8, 9], they are mostly independent and uncoordinated initiatives implemented by individual researchers. To harness the full potential of UK-China collaboration, it is crucial and timely, therefore, to promote a systematic, long-term, and sustainable joint research initiative between the UK and China in wireless communications.

1.3. UK-China Science Bridges: R&D on (B)4G Wireless Mobile Communications

The UK-China Science Bridges: R&D on (B)4G Wireless Mobile Communications (UC4G) project[4] was awarded by the Research Councils UK (RCUK) in December 2008 as one of the four prestigious UK-China Science Bridges projects. The purpose of the UC4G project is to promote systematic, long-term, and sustainable collaboration between the UK and China in the R&D of (B)4G and future wireless mobile communication systems. Specifically, the aims are

1) To become fully connected with top universities and telecom companies that are playing key roles in the (B)4G R&D and standardisation activities in China;
2) To build on the existing substantive collaboration among key UK-China consortium members and further strengthen and broaden current research links;
3) To create, initially, a UK-China panel within Mobile VCE and, ultimately, a UK-China Joint R&D Centre for Future Wireless Communication Networks, enabling long-term sustainable collaboration between the UK and China by supporting collaborative research, mutual visits, exchange of researchers, and rapid technology transfer and commercialisation.

A UK consortium and a China consortium have been created through the UC4G project to bring together the leading expertises in the UK and China in the area of (B)4G wireless mobile communications. As shown in Table 1, the China consortium consists of 7 academic partners and 6 industrial partners led by WiCO, which

[4] EPSRC Grant Reference: EP/G042713/1 (http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/G042713/1); Duration: 1 August 2009-31 July 2009; Value: £ 939,623; More Information is available on http://uc4g.eps.hw.ac.uk/.

is recognised by the Ministry of Science and Technology (MOST) in China as the international centre for wireless collaborative research. All the Chinese partners are key players in (B)4G wireless research. In the UK consortium (Table 2), there are 6 academic partners led by HWU, while Mobile VCE leads the industrial partners involving 15 industrial members. In addition, there are 4 top UK universities as associate academic members.

Table 1: China Consortium

Academic Partners (in alphabetic order)	1) Beijing University of Posts and Telecommunications (BUPT), Wireless Technology Innovation (WTI) Institute, Prof. Ping Zhang (Director) and Prof. Xiaofeng Tao (Vice Director). 2) Huazhong Univ. of Sci. & Techno. (HUST), Dept. of Elec. and Info. Eng., Prof. Xiaohu Ge. 3) Shandong University (SDU), Sch. of Information Sci. & Eng., Prof. Dongfeng Yuan (Dean). 4) Shanghai Jiaotong Univ. (SJTU), Institute of Wireless Commun. Technol., Prof. Youyun Xu. 5) Southeast University (SEU), Sch. of Information Sci. & Eng., Prof. Xiaohu You (Dean, Director of the China FuTURE project). 6) Tsinghua University (THU), Sch. of Information Sci. & Technology, Prof. Zhisheng Niu (Deputy Dean) and Prof. Zhigang Cao. 7) Xidian University (XDU), Sch. of Telecommunications, Prof. Jiandong Li (Director of State Key Laboratory of Integrated Service Networks) and Prof. Hailin Zhang (Dean).
Industrial Partners	1) Shanghai Research Centre for Wireless Communications (WiCO), Prof. Song-Lin Feng (Vice Chairman). 2) Huawei Technologies Co., Ltd, Corporate Research Dept., Mr Jun Shu (Vice President); 3) ZTE, R&D Cooperation Department, Mr Tao Zhang (Director). 4) China Mobile Communications Co., Research Institute, Dr Chunfeng Cui (Project Manager). 5) Jushri Wireless Technologies, Inc., Shanghai, Prof. Zhiyong Bu (CEO). 6) China Academy of Telecommunication Research (CATR), China Telecommunication Technology Labs, Prof. Gui-Li He (Director) and Prof. De-Nian Shi (Chief Engineer).

Table 2: UK Consortium

Academic Partners	1) Heriot-Watt University (HWU), JRI-SIP, Dr Cheng-Xiang Wang. 2) University of Edinburgh (UoE), JRI-SIP, Prof. Peter Grant (FREng, FRSE, FIET, FIEEE, EURASIP Fellow) and Dr Harald Haas. 3) University of Bristol, CCR, Prof. Joe McGeehan (FREng, FIET) and Prof. Mark Beach. 4) University of Southampton, Commun. Group, Prof. Lajos Hanzo (FREng, FIET, FIEEE). 5) University of Bedfordshire, Centre for Wireless Network Design (CWiND), Prof. Jie Zhang. 6) University College London (UCL), Dept. of Electronic & Electrical Eng., Dr Yang Yang.
Associate Industrial Partner	1) Mobile VCE, Dr Walter Tuttlebee (Chief Executive).
Associate Academic Partners (in alphabetic order)	1) King's College London, CTR, Prof. Hamid Aghvami (FREng, FIET, FIEEE). 2) University of Strathclyde, Dept. of Electronic & Electrical Engineering, Prof. Ivan Andonovic and Dr Ian Glover. 3) University of Surrey (UoS), CCSR, Prof. Zhili Sun and Prof. Rahim Tafazolli. 4) University of York, Department of Electronics, Prof. Alister G. Burr.

With a total duration of 3 years, the UC4G project is further broken down into the following 6 work packages (WPs)

- WP1: A delegation of 22 UK academic researchers and industrial participants will visit Chinese institutions and companies, including a technical workshop.
- WP2: Exchange of 30 researchers between UK and Chinese universities
- WP3: Joint-organisation of two four-day international workshops
- WP4: Prototype development and test of (B)4G wireless communication technologies
- WP5: Direct commercialisation of mature (B)4G technologies
- WP6: A delegation of 25 Chinese academic researchers and industrial participants will visit UK institutions and companies, including a three-day final project workshop.

The projected timeline of the UC4G project is illustrated by the following Gant Chart.

WP	YEAR 1				YEAR 2				YEAR 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1												
WP2												
WP3												
WP4												
WP5												
WP6												

1.3.1 Work Package 1: Mission to China

The main activities of WP1 are a visit to the Chinese partners by a UK delegation and an open workshop attended by all the consortium members to discuss collaboration opportunities and future plans. The aim is to promote knowledge exchange in (B)4G wireless communications among Chinese and UK consortium members and further strengthen and broaden current collaboration links. Specifically, the principal objectives of the mission to China are as follows.

- To build familiarity among all Chinese and UK consortium members and reinforce the consensus of the UC4G project.
- To facilitate direct dialogues between the Chinese and UK consortium members to share their research strengths, on-going activities, methodologies, experience, contributions, and future plans on (B)4G technologies.
- To discuss collaboration opportunities such as exchange of researchers, sharing of research resources, and rapid technology transfer and commercialisation.
- To obtain wider awareness and support of the UC4G project and to explore the possibility of securing future funding from, e.g. the Engineering and Physical Sciences Research Council (EPSRC), UK and National Natural Science Foundation of China (NSFC), to support long-term sustainable collaboration between the UK and China.

The above aims and objectives have been successfully achieved through a 14-day visit to China from 26 July 2009 to 8 August 2009, during which a delegation of 22 UK experts (19 sponsored by the UC4G project and 3 sponsored by the DC-KTN) visited 12 key telecom players (including 7 universities and 5 companies) in China to learn about their activities and identify collaboration opportunities in R&D of (B)4G mobile communication systems.

This report summarises the main activities and key findings of our fruitful 14-day visit to China.

2. UK Delegation Members

Affiliation	UK Delegation Member (22)	Position/Title
Heriot-Watt University	Dr Cheng-Xiang Wang Dr Xuemin Hong	Lecturer, PI of the project Postdoc, Network Manager of the project
University of Edinburgh	Dr Harald Haas	Reader
University of Bristol	Prof. Joe McGeehan Prof. Siyuan Yu	Director of the Centre for Communications Research Managing Director of Toshiba's Telecommunications Research Laboratory Chair in Photonics and Optical Communications
University of Southampton	Prof. Lajos Hanzo	Head of Communications Research Group
University of Bedfordshire	Prof. Jie Zhang	Director, Centre for Wireless Network Design (CWiND)
University College London	Dr Yang Yang Dr Kai-Kit Wong Dr Kenneth Tong	Senior Lecturer Senior Lecturer Lecturer
King's College London	Dr Xiaoli Chu	Lecturer
University of York	Prof. Alister Burr	Professor
University of Strathclyde	Prof. Ivan Andonovic Dr Robert Atkinson	Director of Scottish Research Partnership in Engineering (SRPe): Communications Technology Partnership Head of Broadband Networks Group Lecturer
University of Surrey	Prof. Zhili Sun	Chair of Communication Networking
Mobile VCE	Dr Walter Tuttlebee	CEO
BT	Dr Xuanye Gu	Senior Research Scientist and Project Manager
Telecom Modus Ltd. (NEC Subsidiary)	Mr Simon Fletcher	Senior Manager for Future Systems Architecture; Industrial Chair for Mobile VCE Core 5 Green Radio Programme
Turner	Ms Melanie Stewart	Director of Wireless Technologies
Swanmesh	Dr Xinheng Wang	Manager
ixAssociates Limited	Mr Sati Bains	Director
National Physical Laboratory (NPL)	Dr Tian Hong Loh	Senior Research Scientist

Note that Dr Xinheng Wang, Mr Sati Bains, and Dr Tian Hong Loh were sponsored by the DC-KTN, while the rest 19 delegation members were sponsored by the UC4G project.

Biographies:

1. **Cheng-Xiang Wang** received the BSc and MEng degrees in Communication and Information Systems from Shandong University, Shandong, China, in 1997 and 2000, respectively, and the PhD degree in Wireless Communications from Aalborg University, Aalborg, Denmark, in 2004.

   Dr Wang has been a Lecturer at the Joint Research Institute for Signal and Image Processing (JRI-SIP), Heriot-Watt University, Edinburgh, UK since 2005. He is also an Honorary Fellow of the University of Edinburgh, UK, a Guest Researcher of Xidian University, China, and an Adjunct Professor of Guilin University of Electronic Technology, China. He was a Research Fellow at the University of Agder, Grimstad, Norway, from 2001-2005, a Visiting Researcher at Siemens AG-Mobile Phones, Munich, Germany, in 2004, and a Research Assistant at Technical University of Hamburg-Harburg, Hamburg, Germany, from 2000-2001. His current research interests include wireless channel modeling and simulation, cognitive radio networks, green radio networks, vehicular communication networks, cooperative (relay) communications, cross-layer design of wireless networks, MIMO, OFDM, UWB,

and 4G wireless communications and beyond. He has published 1 book chapter and over 120 papers in refereed journals and conference proceedings.

Dr Wang serves as an Editor for 4 international journals: IEEE Transactions on Wireless Communications, Wireless Communications and Mobile Computing Journal (John Wiley & Sons), Security and Communication Networks Journal (John Wiley & Sons), and Journal of Computer Systems, Networks, and Communications (Hindawi). He is the leading Guest Editor for IEEE Journal on Selected Areas in Communications, Special Issue on Vehicular Communications and Networks. He served or is serving as a TPC member, TPC Chair, and General Chair for more than 50 international conferences. Dr Wang is listed in "Dictionary of International Biography 2008 and 2009", "Who's Who in the World 2008 and 2009", "Great Minds of the 21st Century 2009", and "2009 Man of the Year". He is a Senior Member of the IEEE, a member of the IET, and a Fellow of the HEA.

2. **Xuemin Hong** received his Ph.D. degree in 2008 from Heriot-Watt University, UK. He is currently a postdoctoral Research Associate at Heriot-Watt University and the Network Manager for the UK-China Science Bridges project: R&D on (B)4G Wireless Mobile Communications. From January 2009 to July 2009 he was a Post-doc Fellow at the University of Waterloo, Canada. From 2004 to 2005, he was affiliated with King's College London, UK. Dr. Hong has published 17 technical papers in major international journals and conferences and 1 book chapter in the area of wireless communications. His research interests include cognitive radio networks, wireless propagation channel modelling, multiple antenna technologies, and ultra-wideband systems. He is a member of IEEE.

3. **Harald Haas** received the PhD degree from the University of Edinburgh in 2001. His main research interests are in the areas of wireless system engineering and digital signal processing, with a particular focus on interference aware MAC protocols, multiuser access, link adaptation, scheduling, dynamic resource allocation, multiple antenna systems and optical wireless communication. From 2001 to 2002, Haas was project manager at Siemens AG (Information and Communication Mobile Networks) for an international research project involving German and Chinese universities on new radio access technologies. He joined International University Bremen (Germany), now Jacobs University Bremen, in September 2002 where he has since been Associate Professor of Electrical Engineering. In June 2007, he joined the University of Edinburgh (Scotland/UK) where he is Reader in the Institute for Digital Communications (IDCOM). Haas received a best paper award at the International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC) in Osaka/Japan in 1999 and holds more than 15 patents in the area of wireless communications. Haas contributed a chapter to the "Handbook of Information Security" entitled "Air Interface Requirements for Mobile Data Services" by John Wiley & Sons, Inc. He co-authors a book entitled "Next Generation Mobile Access Technologies: Implementing TDD" with Cambridge University Press. This textbook is now being translated into Chinese by the publisher. His work on optical wireless communication was selected for publication in "100 Produkte der Zukunft (100 Products of the Future)" authored by Nobel Laureate T. W. Hänsch. Since 2007 Haas is a *Regular High Level Visiting Scientist* supported by the Chinese "111 program" at Beijing University of Posts and Telecommunications – (BUPT) where he has been invited by Prof. Zhang Ping.

4. **Joe McGeehan** received the Ph.D. and D.Eng. degrees in Electrical and Electronic Engineering from the University of Liverpool in 1971 and 2003 respectively. He is currently Director of the Centre for Communications Research, University of Bristol and Managing Director of Toshiba's Telecommunications Research Laboratory.

   Since 1973 he has been researching spectrum-efficient mobile-radio communication systems and has pioneered work in many areas including linearized power amplifiers, WCDMA (3G) and smart antennas. In particular, current research interests include radio-wave propagation modelling and prediction (particularly for air-to-ground communications), MIMO coding/decoding techniques including Reduced Lattice techniques for 802.11n, LTE, WiMax, etc., Terabit communications, cross-layer research (including video over MIMO wireless links – joint project with UCSD), cognitive radio (with particular reference to Detection and Optimisation and Detection and Avoidance), linearization of RF power amplifiers, computationally efficient EM modelling of deep sub-micron integrated circuits and high speed circuit boards and bio-electronic circuits.

He was joint recipient of the IEEE Vehicular Technology Transactions 'Neal Shepherd Memorial Award' for work on SMART Antennas, and the IEE Proceedings 'Mountbatten Premium' for work on satellite-tracking. He is a Fellow of the Royal Academy of Engineering and was awarded a CBE in 2004 for services to the Communications Industry. In 2004 he was listed as one of the world's top technology agenda setters by silicon.com (USA). He has served on numerous international committees and was advisor to the UK's first "Spectrum Review Committee" in the late 1970s.

5. **Siyuan Yu** was born in Nanchang, Jiangxi Province, China, in May 1963. He received his B. Eng. degree from Tsinghua University, Beijing, China, in 1984, and M. Eng. degree in 1987 from Wuhan Research Institute of Post and Telecommunications, Wuhan, China. He joined the Department of Optoelectronic Engineering, Huazhong University of Science and Technology in 1987 where he worked on semiconductor optical amplifiers and other photonic devices. From 1993 to 1996 he studied for his Ph.D. degree at the Department of Electronics and Electrical Engineering, University of Glasgow, Glasgow, Scotland, UK, working on monolithically integrated photonic devices. In 1996 he joined the Department of Electrical and Electronic Engineering, University of Bristol, England, UK, where he is currently a Professor of Photonics and Optical Communications. Dr Yu is the (co-)author of more than 100 papers and (co-)inventor of several patents.

6. **Lajos Hanzo**, received his Masters degree in electronics in 1976 and his Doctorate in 1983 from the Technical University of Budapest. In 2004 he was awarded the Doctor of Sciences (DSc) degree by the University of Southampton, UK. During his 30-year career in telecommunications he has held various research and academic posts in Hungary, Germany and the UK. Since 1986 he has been a member of academic staff in the School of Electronics and Computer Science, University of Southampton, UK, where he currently holds the Chair in Telecommunications and is head of the Communications Research Group.

   Lajos Hanzo has co-authored 17 John Wiley/IEEE Press books totalling about 10 000 pages on mobile radio communications, and published about 865 research papers. He has also organised and chaired conference sessions, presented Tutorial/overview lectures, as well as presenting about 470 papers at international conferences. He has also presented a number of named lectures and keynotes.

   Lajos is also an IEEE Distinguished Lecturer of both the Communications Society and the Vehicular Society as well as a Fellow of both the IEEE and the IEE/IET, Fellow of the Royal Academy of Engineering (FREng). He is acting as a Governor of the IEEE VTS as well as of ComSoc. Lajos is the Editor-in-Chief of the IEEE Press. has and been awarded a number of distinctions.

7. **Jie Zhang** is a *Professor of Wireless Communications and Networks* at the DCST (Department of Computer Science and Technology) of UoB (University of Bedfordshire). He joined UoB as a Senior Lecturer in 2002, becoming Reader and Professor in 2005 and 2006 respectively.

   Prof. Zhang received his PhD in *Industrial Automation* from *East China University of Science and Technology* (www.ecust.edu.cn), Shanghai, China, in 1995. From 1997 to 2001, he was a postdoctoral Research Fellow (RF), working with some of the most reputable research groups in *Process Control/Process Systems Engineering* at *University College London (UCL)*, *Imperial College London*, and *Oxford University***.** In 2001, Prof. Zhang briefly worked with Aircom (as a *Software Engineer*), where he gained an interest in radio network planning and optimisation. In 2002, he came back to academia to search for solutions for the problems he identified at Aircom.

   Since 2003, as the Principal Investigator, Dr Zhang has been awarded more than 10 projects worth over €4.0 million (his share) by the EPSRC and the EC (FP6/FP7), etc. He is a Co-Investigator of two EPSRC projects. In addition, Prof. Zhang is responsible for projects worth a few million Euros at his industrial partners. These projects are centred on new radio propagation models, UMTS/HSPA/WiMAX/LTE simulation, planning and optimization, indoor radio network design and femtocells.

   He is an evaluator and sits on the judging panels for both EPSRC (Engineering and Physical Science Research Council, equivalent to NSF of China; www.epsrc.ac.uk) and the EU Framework Program (FP).

He is a **lead author** of the first comprehensive technical book on femtocells "***Femtocells – Technologies and Deployment***", which will be published by Wiley in Q4 2009. He has published over 100 refereed journal and conference papers (e.g., *IEEE JSAC, IEEE TWC, IEEE Com. Mag., IEEE Network*, etc). He is **the chair of a femtocell panel** titled "Femtocells: Deployment and Applications" at IEEE ICC 2009. He has been a panellist at IEEE Globecom and IEEE PIMRC.

Prof. Zhang is an Associate Editor of *Telecommunication Systems* (Springer).

He is the *Director of CWiND* (Centre for Wireless Network Design, www.cwind.org), one of the best-funded, one of the largest and leading research groups in radio network planning and optimisation in Europe. In particular, CWiND is the world leader in **indoor wireless network design** and **femtocells**. CWiND hosted the first EPSRC-funded research project on femtocell and published some ground breaking work in femtocells in *IEEE Communications Magazine* and other journals and conferences. CWiND members authored the first comprehensive technical book on femtocells.

Apart from this role as a Professor, Dr. Zhang serves as the *Chief Technology Officer* (CTO) of two SMEs.

8. **Yang Yang** received the BEng and MEng degrees in Radio Engineering from Southeast University, Nanjing, P. R. China, in 1996 and 1999, respectively; and the PhD degree in Information Engineering from The Chinese University of Hong Kong in 2002.

   He is currently a Senior Lecturer with the Department of Electronic and Electrical Engineering at University College London (UCL), United Kingdom. Prior to that, he served the Department of Information Engineering at The Chinese University of Hong Kong as an Assistant Professor from Aug. 2002 to Aug. 2003, and the Department of Electronic and Computer Engineering at Brunel University, United Kingdom, as a Lecturer from Sept. 2003 to Feb. 2005. His general research interests include mobile ad hoc networks, wireless sensor networks, wireless mesh networks, third generation (3G) mobile communication systems and beyond, dynamic radio resource management (RRM) for integrated services, cross-layer algorithm design and performance evaluation, cognitive radio and networks, cooperative communications, and medium access control (MAC) protocols. He is a member of the IET and a member of the IEEE.

9. **Kai-Kit Wong** received the BEng, the MPhil, and the PhD degrees, all in Electrical and Electronic Engineering, from the Hong Kong University of Science and Technology, Hong Kong, in 1996, 1998, and 2001, respectively.

   After graduation, he joined the Department of Electrical and Electronic Engineering, the University of Hong Kong as a Research Assistant Professor. From July 2003 to December 2003, he visited the Wireless Communications Research Department of Lucent Technologies, Bell-Labs, Holmdel, NJ, U.S., where he was a Visiting Research Scholar studying optimization in broadcast MIMO channels. After that, he then joined the Smart Antennas Research Group of Stanford University as a Visiting Assistant Professor conducting research on overloaded MIMO signal processing. From 2005 to August 2006, he was with the Department of Engineering, the University of Hull, U.K., as a Communications Lecturer. Since August 2006, he has been with University College London Adastral Park Campus where he is a Senior Lecturer.

   Dr Wong won the IEEE Vehicular Technology Society Japan Chapter Award of the International IEEE Vehicular Technology Conference-Spring in 2000, and was also a co-recipient of the First Prize Paper Award in the IEEE Signal Processing Society Postgraduate Forum Hong Kong Chapter in 2004. In 2002 and 2003, he received, respectively, the SY King Fellowships and the WS Leung Fellowships from the University of Hong Kong. Also, he was awarded the Competitive Earmarked Research Grant Merit and Incentive Awards in 2003-2004.

   Dr Wong is a Senior Member of IEEE and is also on the editorial board of IEEE Transactions on Wireless Communications, IEEE Communications Letters, IEEE Signal Processing Letters, IET Communications, and Journal of Communications, Academic Publisher. His current research interests center around cognitive radio, cooperative wireless networks, cross-layer optimisation, information theory and optimisation, multiuser communications theory, performance analysis of MIMO channels, and secrecy capacity of wireless channels.

10. Dr **Kin-Fai Tong** obtained his PhD degree from City University of Hong Kong in 1997. He has a strong track record in antenna design and microwave / millimetre-wave measurement. Before joining the Sensors, Systems and Circuits Group (SSCG), he was an Expert Researcher in the Photonic and Millimetre-wave Devices Group in National Institute of Information and Communications Technology (NiCT) Japan for almost five years. NiCT is the sole national research institute in information and communications in Japan. Dr Tong has rich experience in working on novel and creative antenna structures for different applications. Early in 1994, Dr Tong introduced the idea of integrating microstrip patch antennas into mobile phone handsets in the Asia Pacific Microwave Conference, which is believed to be the first presentation of the subject in international conferences. Moreover, he collaborated with Prof K.F. Lee, Dean, School of Engineering, University of Mississippi, USA, pioneering the development of Finite Difference Time Domain (FDTD) electromagnetic modelling for investigating the ultra-wideband behaviour of U-slot microstrip patch antennas, the work has already received more than a hundred citations in the past few years. His work in low-k materials for mm-wave antennas for microwave photonic integrations was granted an Incentive Research Fund NiCT successfully. Dr Tong is an active TPC member, session organiser and chairman of many international antennas and microwaves conferences. He has co-authored two book chapters on planar antenna designs and is author or co-author of over 50 publications. In his early stage of academic career in UK, Dr Tong plans to establish an Antennas and Microwaves research group of international standing, based on his connections across China, Japan and UK. His role in this work is to manage the project and provide technical advice in electromagnetic modelling, antenna design and experimental evaluation of the prototypes.

11. **Xiaoli Chu** received the B.Eng. degree with first class honors in Electronic and Information Engineering from Xi'an Jiao Tong University (XJTU), Xi'an, P. R. China, in July 2001, and the Ph.D. degree in Electrical and Electronic Engineering from the Hong Kong University of Science and Technology (HKUST), Hong Kong, in August 2005. From September 2005 to December 2006, she worked as a postdoctoral research associate at King's College London. She has been a Lecturer with the Department of Electronic Engineering at King's College London since January 2007. Her general research interests include wireless communication systems, ultra-wideband (UWB) radio technologies, and wireless sensor networks. Her current research extends to advanced technologies for link performance improvement and system capacity enhancement, such as cooperative communications, adaptive radio resource management, multidimensional diversity schemes, and methods for mitigating detrimental effects from hostile wireless environments.

12. **Alister Burr** was born in London, U.K, in 1957. He received the BSc degree in Electronic Engineering from the University of Southampton, U.K in 1979 and the PhD from the University of Bristol in 1984. Between 1975 and 1985 he worked at Thorn-EMI Central Research Laboratories in London. In 1985 he joined the Department of Electronics at the University of York, U.K, where he has been Professor of Communications since 2000. His research interests are in wireless communication systems, especially modulation and coding and including turbo-codes and turbo-processing techniques, and MIMO and cooperative systems. He has published more than 150 papers in refereed international conferences and journals, and is the author of "Modulation and Coding for Wireless Communications" (published by Prentice-Hall/PHEI). In 1999 he was awarded a Senior Research Fellowship by the U.K. Royal Society, and in 2002 he received the J. Langham Thompson Premium from the Institution of Electrical Engineers. He has also held a visiting professorship at Vienna University of Technology, and given numerous invited presentations, including at the First International Conference on Turbocodes and Related Topics, and a keynote at the first WCNC event (now IEEE WiCom), Wuhan, China. He is currently chair, working group 1, of the European COST 2100 programme "Pervasive Mobile and Ambient Wireless Communications".

13. **Ivan Andonovic**, an ITI Techmedia Professor of broadband networks, joined the Electronic and Electrical Engineering Department at the University of Strathclyde in 1985, following a three-year period as a Research Scientist (at Barr & Stroud) responsible for the design, manufacture, and test of guided wave devices for a variety of applications. His main interests centre on optical networks, photonic switching and routing, optical code division multiple access, wireless sensor networks and wireless ad-hoc networking. He was holder of a two-year Royal Society Industrial Fellowship in collaboration with BT Labs, during which time he was tasked with investigating novel approaches to

networking. He has edited two books and authored/co-authored five chapters in books and over 230 journal and conference papers. He has been Chairman on the IEE Professional Group E13, held a BT Short Term Fellowship, Visiting Scientist status at the Communications Research Laboratories of Japan, and Visiting Professor at the City University of Hong Kong and Princeton University. He was cofounder, Director, and Chief Technology Officer of Kamelian Ltd., a highly growing technology start-up focusing on the design and manufacture of advanced optical semiconductor devices. He was also a Member of flagship Scottish Enterprise (government agency for economic growth) establishment team of the Intermediary Technology Institutes (ITIs), aimed at bridging the gap between basic research and company growth. Presently, he holds the ITI Techmedia Sponsored Chair in Broadband Networks facilitating the interaction between fundamental research in communications technologies and digital media and precompetitive development of technologies that will form the input to commercialization activities in Scotland. Professor Andonovic is a Fellow of the IET, holds Senior Member status within the IEEE, and is a Member of the EPSRC College 2006.

14. Dr **Robert C Atkinson** obtained a BEng (Hons) degree from the University of Strathclyde in 1993. He subsequently obtained an MSc in Communications, Control and Digital Signal Processing in 1995 and a PhD in Mobile Communications Systems in 2003 from the same institution. He is now a Lecturer in the Centre for Intelligent Dynamic Communications (CIDCOM), Department of Electronic and Electrical Engineering, University of Strathclyde. He has operated as an active researcher in a number of industrially focused research programmes, notably as a Lead Researcher in the UK's Mobile VCE Personal Distributed Environment Work Area. His European research projects include the FP6 funded project, Multinet. His active research interests include Next Generation Networking paradigms, Future Internet Technologies, Mobility Management Protocols, Wireless Characterisation, Autonomic Networking, and emerging 4G systems. He is a Member of the IET and a Senior Member of the IEEE.

15. Professor **Zhili Sun** got his BSc in Mathematics from Nanjing University, China, in 1982, and PhD in Computer Science from Lancaster University, UK, in 1990. He worked as a postdoctoral research fellow in the Telecommunication Research Group, Queen Mary University of London from 1989 to 1993. He was principal investigator and technical co-ordinator in many European projects including the ESPRIT BISANTE project on evaluation of broadband traffic over satellite using simulation approach, VIP-TEN project on Quality of Service (QoS) of IP telephony over satellite, EU 5th and 6th Framework Programme GEOCAST project on IP Multicast over satellites, ICEBERGS project on IP based Multimedia Conference over Satellite, SatLife project on IP over DVB-S/RCS, SATSIX project on IPv6 over satellite, Euro-NGI project on next generation Internet, RINGRID project on remote instrumentation over GRID computing, and EC-GIN project on EU-China Grid Internetworking. He has also been a principal investigator projects funded by the UK Electronics and Physical Sciences Research Council, European Space Agency (ESA) and industries. He has supervised many PhDs and research fellows. He has published over 125 papers in International journals, book chapters and conferences, has published a book as sole author titled “satellite networking – principles and protocols” by Wiley in 2005, and a contributing editors of another book “IP networking over next generation satellite systems”. He also contributed to revise the 5th edition of the text book “Satellite Communications Systems – systems, techniques and technology” to be published by Wiley in 2010. He acted as technical reviewer of EU framework programmes and EPSRC proposals. He is also an active contributor to ITU-T and ETSI in QoS and IP multicast over satellite. He has been general chair and member of technical committees of international conferences and member of reviewers of major EU and UK research proposals. He has acted as external examiner for PhD viva in many universities in UK, France, Spain, Singapore, Sweden and China. He also teaches MSc, undergraduate and industrial courses on IP networking protocols and technologies, satellite networking, Internet and teletraffic engineering, network security and mobile operating systems.

16. **Walter Tuttlebee** has led the Virtual Centre of Excellence in Mobile & Personal Communications (Mobile VCE) since 2000. Established in 1996, Mobile VCE has a global industry membership which defines & steers programmes of strategic research, harnessing the leading UK research Universities to deliver world-class, industry-led, research, across a wide range of wireless, networks, software and user technologies. As Chief Executive Walter is responsible for the organisation and operation of Mobile VCE and its strategic research for its member companies – principally global telecom manufacturers and operators from Europe, America and Asia – as well as its relations with the UK and overseas

Governments. Mobile VCE's industrial members include: Alcatel-Lucent, BBC, BT, Fujitsu, Huawei, Hutchison, NEC, Nokia Siemens Networks, Nortel, Orange (France Telecom), Samsung, Thales, Toshiba, Turner and Vodafone.

Prior to his current role, Walter worked for Plessey and, later, Siemens, where he held responsibility for standardisation, research and product development in DECT, GSM and 3G technologies, subsequently adopting a broader business development and consultancy role in personal communications, digital broadcasting and satellite communications. Walter has chaired and contributed to many international communications conferences and journals, in recent years focussing upon the strategic options and commercial implications of emerging technologies. He has also published several books, including "Cordless Telecommunications Worldwide" and the Wiley book series on Software Radio.

Whilst with Mobile VCE, Walter has led business missions to China, Japan, Korea and North America, working with industry, academia and Governments and has served on Ofcom's Spectrum Advisory Board and the Expert Advisory Group to the eMobility Technology Platform, and is a Director of the Digital Communications Knowledge Transfer Network.

Walter holds an MBA from Cranfield University, and BSc and PhD degrees from Southampton University. In 2008 he was made an Officer of the Order of the British Empire in the Queen's Birthday Honours, for services to the telecommunications industry.

17. **Xuanye Gu** has over 20 years experience in a variety of technology areas and has been working in mobility and wireless communications since 2002. In 1997, He joined BT, a global company and operator of networked ICT solutions, broadband, mobility, data and voice services, where he has served as senior research scientist and a research manager in the mobility and convergence centre. His current research areas include dynamic spectrum access using cognitive radio, spatial diversity in wireless networks, multiple antennas systems, technology and economic analysis for wireless networks and frequency channel allocations for wireless LANs. From 1997 to 2002, he worked in the complex systems lab, BT, on several other projects including ultra-wide band systems, wireless multiple access systems and data traffic analysis and modelling. From 1989 to 1997, he carried out optical research, as a PhD candidate and a research fellow in BT Labs. His optical research work involved investigations on laser modulations, coherent transmission, semiconductor laser and fibre amplifiers, design of dispersion compensation devices and circuits, wavelength division multiplexing and the effect of fibre nonlinearity in long haul submarine systems. From 1982 to 1987, he was an engineer and deputy manager with the Shanghai Telecommunications Ltd, a vendor of digital and optical systems and various telecommunications equipment, under the ministry of posts and telecommunications of China. He received a B.Eng. degree in Telecommunications Engineering from the University of Posts and Telecommunications, Nanjing, China in 1982, a MBA degree from the Queen's University of Belfast, UK in 1988, and a PhD degree in Electrical Engineering from the University of East London, UK in 1992. He is a member of IEEE and IEEE Communication Society.

18. **Simon Fletcher** is a Senior Manager for Future Systems Architecture, Radio Systems Division, Telecom MODUS Ltd. (an NEC subsidiary company).

Simon Fletcher has responsibility for the development of technology strategy and emerging Global Market products in partnership with NEC, primarily in the area of Radio access technologies. Telecom Modus was established in 1998 and has been active in the development of 3GPP Standards and core technologies for products since. Simon attends CPRI (Common Public Radio Interface) standardisation and LSTI (LTE SAE Trial Initiative) as NECs Proof of Concept and Steering Group representative. Simon takes responsibility for Standardisation (primarily 3GPP) strategy discussions and takes part in pre-Standards research pull through and is NECs primary contact for MVCE. Other responsibilities include attendance of the (DC-KTN) Digital Communications Knowledge Transfer Network on behalf of NEC and Project Manager for the development of LTE Baseband systems.

Prior to his current role Simon worked for NEC in establishing the Joint Venture between NEC and Siemens AG for the development of World Market UMTS equipment. Simon held various roles during his engagement with the joint venture including Project Manager of Software development; core interface definition team leader; System Architect for HSDPA solutions and ultimately Consultant to Product Line Management and Roadmap development groups. Prior to working for NEC Simon

worked as a group manager in the Advanced Systems Department in Racal Defence, designing and implementing Proof of Concept demonstrators for the Defence Evaluation Research Agency.

Simon is the Industrial Chair for the MVCE Core5 Green Radio Programme. The Industrial Chair is responsible for communications approach to organisations/companies both within and external to MVCE, and assurance of the industrial relevance (impact) of the research; working in partnership with MVCE Management and the other industrial members of MVCE.

Simon Fletcher holds a Masters in Engineering in Electronics and Electrical Engineering from the University of Surrey.

19. **Melanie Stewart** has a Bachelor of Applied Science in Computer Science from RMIT University in Melbourne, Australia. She is currently a Director of Wireless Technologies, Platform Research & Development in Turner (a Mobile VCE industrial member). She is responsible for investigation and assessment of emerging mobile and broadband technologies including 2D-3D conversion, audience data monetisation, advanced advertising techniques and the exploitation of content ecosystems and future wireless devices.

20. Dr. **Xinheng (Henry) Wang** is the founder and executive manager of Swanmesh Ltd and a senior lecturer in wireless communications in Institute of Advanced Telecommunications, Swansea University. He graduated from Xi'an Jiaotong University with a BEng and an MSc degree in 1991 and 1994, respectively, and obtained his PhD degree from Brunel University in 2001. He then worked as a post-doctoral research fellow at Brunel from June 2001. He joined Kingston University in 2003 as a senior research fellow and was promoted to a senior lecturer in June 2004. In September 2007 he joined the IAT to take up the senior lectureship. He is also a visiting professor at University of Electronic Science and Technology of China.

    His current research interests are wireless mesh and sensor networks, software defined radios and cognitive radio networks, and their applications in healthcare. He is currently investigating several funded research projects supported from government and industry, including 2 EPSRC projects, 1 EPSRC doctoral training project, 1 China 863 project, and 1 China innovation fund project.

    He is a member of IEEE and serves as an associate editor for Network Protocols and Algorithms.

21. Mr **Sati Bains** is the Director of ixAssociates. He has been directly involved in the successful delivery of information, communication and technology programmes, with over 15 years experience. He has held direct responsibility for creating audit methodologies for mobile technologies, implementing and introducing new technology, managing vendor relationships and day-to-day operational business management.

    Since 2004, he has focused on the development of new learning technologies (including mobile devices) and the associated security systems and infrastructure. He is currently working on the next evolution of EU data protection and privacy standards and have presented on behalf of European standards agency. His focus is on to excel in the development of information risk and governance strategies within new and emerging technologies with the wider impact on operational information.

    His previous experiences includes building niche security consulting practices at both IBM and at Andersen's.

22. **Tian-Hong Loh** received, respectively, the B.Eng. degree (first-class) from The Nottingham Trent University (TNTU), Nottingham, U.K., in 1999, and the PhD degree from University of Warwick, Coventry, U.K., in 2005, both in in electrical and electronic engineering. From 1999 to 2000, he was an Electrical Engineer with SHARP–ROXY Inc., Batu Pahat, Malaysia. He joined the U.K. National Physical Laboratory in 2005 as Higher Research Scientist and since 2009, he has been a Senior Research Scientist, involved in work on fundamental research and develop measurement technologies in support of the electronics and communication industry.

    His current research interests include small & smart antenna, metamaterials for application on antennas and microwaves devices, wireless signal propagation, interference data transfer & data clustering in wireless communication networks such as WLAN, Bluetooth, UWB, ZigBee, etc., MIMO channel

characterisation and modelling, computational electromagnetics, in particular, the time-/frequency-domain finite-element modeling and experimental characterization of microwave devices, and electromagnetic compatibility.

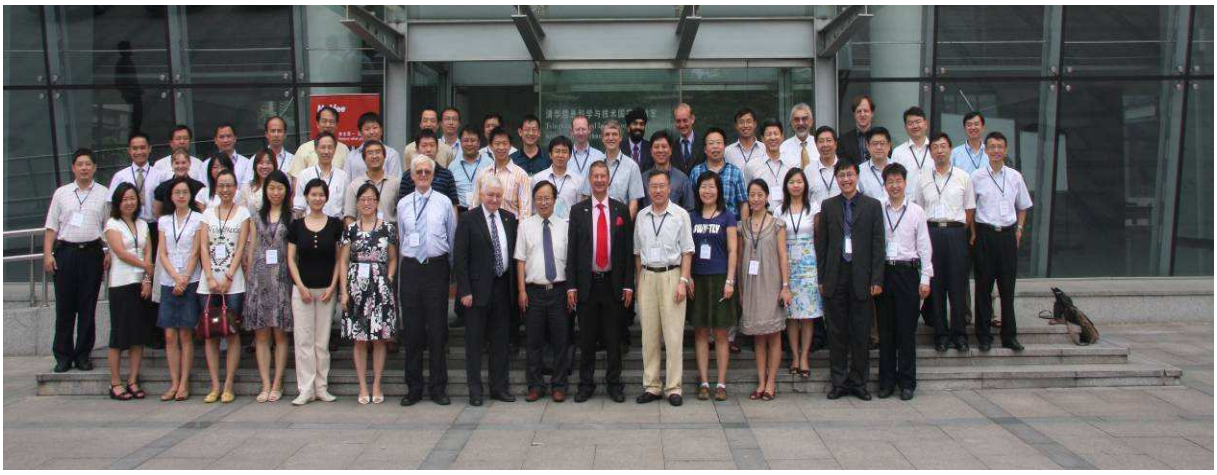
3. Travel Itinerary

Our visit to China took place from 26 July to 9 August 2009. The detailed travel itinerary and activities are summarised as follows.

Date	City	Time	Activity
Sun. 26 July	Shanghai	-	The UK delegation arrived in Shanghai
Mon. 27 July	Shanghai	09:30-13:30	Visit Shanghai Research Center for Wireless Communications
		14:30-17:00	Visit Jushri Wireless Technologies Inc.
		18:30-20:30	Reception hosted by British Consulate-General Shanghai
Tues. 28 July	Shanghai	09:30-13:00	Visit Huawei Technologies Co. Ltd
		14:30-19:30	Visit Shanghai Jiaotong University (SJTU)
Wed. 29 July	Nanjing	14:00-20:00	Visit Southeast University (SEU)
Thur. 30 July	Wuhan	14:30-20:00	Visit Huazhong University of Science & Technology (HUST)
Fri. 31 July	Xi'an	14:30-20:00	Visit Xidian University (XDU)
Sat. 1 Aug.	Xi'an	-	Tour of Xi'an organized by XDU
Sun. 2 Aug.	Jinan	-	The UK delegation travelled from Xi'an to Jinan
Mon. 3 Aug. 3	Jinan	09:30-14:30	Visit Shandong University (SDU)
Tues. 4 Aug.	Beijing	08:00-21:00	Workshop at Tsinghua University, Day 1
Wed. 5 Aug.	Beijing	08:00-17:30	Workshop at Tsinghua University, Day 2
		17:30-20:30	Visit Tsinghua University
Thur. 6 Aug.	Beijing	08:30-13:30	Workshop at Tsinghua University, Day 3
		14:30-20:00	Visit Beijing University of Posts and Telecommunications
Fri. 7 Aug.	Beijing	09:00-13:00	Visit China Mobile Communication Co.,
		14:30-20:00	Visit China Academy of Telecommunication Research, CTTL Labs
Sat. 8-9 Aug.	Beijing	-	The UK delegation left Beijing

4. Beijing Workshop

A two-and-a-half day open workshop was held at Tsinghua University (THU), Beijing, from 4 to 6 August 2009. In this workshop, the UK delegation was joined by delegates from all our Chinese partner organisations as well as researchers from other organisations to share the research strengths of each partner, discuss collaboration opportunities, and plan future activities for the UC4G project. The detailed programme of the workshop and the attendee list are provided in this section.



4.1 Programme of Beijing Workshop 2009

Tuesday 04/08	8:00-8:30	Registration
	8:30-9:40 Chair: Prof. Zhisheng Niu	**Welcome speeches**: 1) Prof. Yonghua Song, Assistant President, THU 2) Mr Jijun Xing, Director of Europe, Department of International Collaboration, MOST 3) Mr Chris Godwin, Director, RCUK China 4) Mr Alastair Morgan, Commercial Counselor and Director of UK Trade & Investment (UKTI) for China
	9:40-10:10	Overview of the project (Dr Cheng-Xiang Wang, PI of the Project & Lecturer at Heriot-Watt University)
	10:10-10:50	Coffee/tea break; **posters**
	10:50-11:40 Chair: Prof. Zhisheng Niu	Keynote speech (Dr Walter Tuttlebee, CEO, Mobile VCE)
	11:40-12:30 Chair: Prof. Zhisheng Niu	Keynote speech: Future Trend of the Wireless Communication Development (Dr Shujun Dang, Chief Research Engineer, Huawei Wireless)
	12:30-13:30	Lunch
	13:30-15:10 Chair: Prof. Dongfeng Yuan	5 Technical Presentations: 1) Tsinghua Univ. 2) Beijing Univ. of Posts & Telecommunications 3) Huazhong Univ. of Science & Tech. 4) Shandong Univ. 5) Xidian Univ.
	15:10-15:50	Coffee/tea break; **posters**
	15:50-17:30 Chair: Prof. Lajos Hanzo	5 Technical Presentations: 1) Southampton Univ. 2) Univ. of Bristol 3) Univ. of Edinburgh 4) Heriot-Watt Univ. 5) Univ. of Strathclyde

	18:00-21:00	Banquet, Quanjude, Tsinghua Science Park,
Wednesday 05/08	8:30-9:20 Chair: Prof. Zhigang Cao	Keynote speech: Cognitive Radio Networks (Prof. Ping ZHANG, Director of WTI Institute, BUPT)
	9:20-10:10 Chair: Prof. Zhigang Cao	Keynote speech: Collaboration and Technology Transfer Between Academia and Industry: Some Case Studies (Prof. Joe McGeehan, Director of CCR, University of Bristol; Managing Director of Toshiba's Telecommunications Research Laboratory)
	10:10-10:50	Coffee/tea break; **posters**
	10:50-12:30 Chair: Dr Xuanye Gu	5 Technical Presentations: 1) WiCo 2) China Mobile 3) Huawei 4) BT 5) Turner
	12:30-13:30	Lunch
	13:30-15:10 Chair: Prof. Alister Burr	5 Technical Presentations: 1) University College London 2) King's College London 3) University of Bedfordshire 4) University of Surrey 5) University of York
	15:10-15:30	Coffee/tea break; **posters**
	15:30-16:30 Chair: Prof. Nan LIU	3 Technical Presentations: 1) ZTE 2) Southeast University 3) Shanghai Jiaotong University
	16:30-18:00	Visit Tsinghua Univ. Labs
	18:30-20:30	Dinner, Ziguang (Unisplendour International Center), Building 10, No.1, Esat Road of Zhongguancun, Haidian District, Beijing100084
Thursday 06/08	8:30-10:10 Chair: Prof. Zhili Sun	5 Technical Presentations: 1) Jushri 2) CATR 3) National Physical Laboratory (NPL) 4) Swanmesh 5) ixAssociates Limited
	10:10-11:00	Coffee/tea break; **posters;** **Project Management Committee (PMC) meeting**
	11:00-12:30	Discussions on collaborations; Discussions on further funding opportunities; Discussion on future work packages; **PMC Q&A**; **Wrap up**
	12:30-13:30	Lunch

4.2. Attendees List

VIPs (8):

Affiliation	Name	Position/Title
THU	Prof. Yonghua Song	Assistant President
MOST	Mr Jijun XING	Director of Europe, Dept. of International Cooperation
NSFC China	Dr Zhaotian Zhang	Vice Director, Department of Information Science
RCUK China	Mr Chris Godwin Ms Grace LANG	Director Deputy Director
UKTI for China	Mr Alastair Morgan Ms Qin LI	Commercial Counselor and Director of UK Trade & Investment (UKTI) for China 2nd Secretary (ICT)
SDI (Beijing office)	Mr Baijin LONG	General Manager

UK Partners (21):

Affiliation	Name	Position/Title
HWU	Dr Cheng-Xiang Wang Dr Xuemin Hong	Lecturer, PI of the project Postdoc, Network Manager of the project
University of Edinburgh	Dr Harald Haas	Reader
University of Bristol	Prof. Joe McGeehan Prof. Siyuan Yu	Director, Centre for Communications Research Chair in Photonics and Optical Communications
University of Southampton	Prof. Lajos Hanzo	Head of Communications Research Group
University of Bedfordshire	Prof. Jie Zhang	Director, Centre for Wireless Network Design (CWiND)
UCL	Dr Yang Yang Dr Kenneth Tong	Senior Lecturer Lecturer
KCL	Dr Xiaoli Chu	Lecturer
University of York	Prof. Alister Burr	Professor of Communications
University of Strathclyde	Dr Robert Atkinson	Lecturer
University of Surrey	Prof. Zhili Sun	Chair of Communication Networking
Mobile VCE	Dr Walter Tuttlebee	CEO
BT	Dr Xuanye Gu Dr Jie ZHANG (Beijing) Dr Quan LI (Beijing)	Senior Research Scientist & Project Manager Head of China Research Centre Strategic Research & Collaboration Manager
Turner	Ms Melanie Stewart	Director of Wireless Technologies
Nokia Siemens Networks (NSN), Beijing	Dr Jun Li Dr. Hao Guan Dr. Yong Teng	Director, Cooperation Department Radio System Technology, PT China, RTP

Chinese Partners (31):

Affiliation	Name	Position/Title
BUPT	Prof. Ping Zhang	Director, WTI Institute
	Dr Qimei Cui	Assoc. Prof.
	Dr Xiaodong Xu	Lecturer
	Dr Yuexia Zhang	Lecturer
HUST	Dr Xiaohu Ge	Assoc. Prof.
SDU	Prof. Dongfeng Yuan	Dean, School of Information Science and Engineering (ISE)
	Prof. Mingyan Jiang	Deputy Dean, School of ISE
	Dr Haixia Zhang	Assoc. Prof.
	Dr Zhiquan Bai	Assoc. Prof.
SJTU	Dr Jing LIU	Lecturer
SEU	Prof. Nan Liu	Professor
THU	Prof. Zhisheng Niu	Deputy Dean, School of Information Science and Technology
	Prof. Zhigang Cao	Deputy Director, Chinese State Key Lab on Microwave & Digital Communications
	Dr Wei Chen	Assistant Prof.
	Ms Ping Xu	Lab Assistant
XDU	Prof. Jiandong Li	Director of State Key Lab of Integrated Service Networks
	Prof. Hailin Zhang	Dean, School of Communications
	Prof. Liqiang Zhao	Professor
WiCO	Dr Honglin Hu	R&D Director for Wireless Technologies
Huawei	Dr. Xuezhi Yang (Beijing)	Senior Research Engineer
	Dr Shujun Dang (Beijing)	Research Chief Engineer, Director
ZTE	Mr Tao Zhang (Shanghai)	Director, R&D Cooperation Department
	Mr Guang Yang (Beijing)	Chief Engineer
China Mobile	Dr Chunfeng Cui	Project Manager, R&D Center
	Dr. Zhigang Yan	
Jushri	Dr. Zhigang Zhou	Assoc. Professor
CATR	Mr. Guili He	Director, China Telecommunication Technology Labs (CTTL)
	Ms Wei Li	Senior Engineer, Deputy Director, Wireline Terminal Commun., CTTL
	Ms Kun Wang	Engineer, Project Manager, Wireline Terminal Communication, CTTL
	Ms Lei Wen	Engineer, Project Manager, Radio Communication Dept., CTTL
	Ms Xiaoli Ma	Engineer, Project Manager, Radio Communication Dept

Other UK Attendees (4):

Affiliation	Name	Position/Title
NPL	Dr Tian Hong Loh	Senior Research Scientist
Swanmesh	Dr Xinheng Wang	Manager
ixAssociates Limited	Mr Sati Bains	Director
University of Essex	Dr Kun Yang	Reader

Other Chinese Attendees (2):

Affiliation	Name	Position/Title
Beijing University	Prof. Bingli Jiao	Director of Insitute of Wireless Communication and Signal Processing
	Prof. Lingyang Song	Professor

5. Key Findings

China has a national strategy to become a major player in the global (B)4G arena. The Chinese government appears to have a clear vision in making strategic investments to achieve world-class R&D capabilities in the (B)4G sector. These government investments are strongly focused on major research programmes, key laboratories and top universities. The funding structure ensures that the high-level government vision can be effectively implemented in a top-down fashion. With strong government supports, major Chinese universities are able to establish large research groups not only to conduct high-quality research, but also to involve heavily in prototype/testbed development activities. Major Chinese companies are able to expand rapidly overseas and are becoming more and more active in all kinds of global standardisation activities.

5.1. Universities

Compared with the UK universities, Chinese universities appear to have focused more on prototype/testbed **development** activities than fundamental research. Through years of experience in prototype/testbed development, top research groups in Chinese universities have accumulated a considerable amount of advanced technologies and know-how skills, which can be easily transferred to the industry.

Despite the huge commitments to development activities, major Chinese universities have put increasing emphasis on conducting **fundamental research**. This has effectively resulted in a rapid growth of the number of papers in top-quality journals originating from Chinese labs in recent years. It is worth noting that many research outputs produced by Chinese labs remain less visible to the world than it should, as they are published in Chinese-language journals seldom cited in the international journals. The increasing international collaboration can help to integrate more research work produced in China into the world knowledge system.

The **size** of the research groups in major Chinese universities is rarely matched by universities in the UK. The number of research staff and students in top Chinese research groups can easily exceed 100. The promising career prospect in the telecom industry in China ensures a continuing supply of capable young researchers to this field.

With huge intellectual banks available, top research groups in Chinese universities are capable of expanding their **research scope** to almost all aspects of (B)4G communications systems, ranging from transmission theory to prototype/testbed development, and from point-to-point links to large-scale networks. Typically, all the research activities within a group are closely coordinated by the group head to form a coherent research force. This is different from the British universities, where in many cases academic members undertake independent and uncoordinated researches.

The university **funding** on research in China is primarily governmental. The funding size of major Chinese universities can easily be ten times larger than that of the universities in the UK. For instance, the National Mobile Communications Research Laboratory at Southeast University received 44.86 million RMB, equivalent to approximately 4.08 million GBP, in Year 2007. Once the major funding from the central government is secured, match funding can be available at the provincial and/or university levels. Much less funding overhead and staff costs in China allows Chinese universities to invest more on infrastructure development, e.g., new labs and equipments, prototype/testbed development, and employment of more research staff/students.

All the visited Chinese universities have created vibrant **interactions with the industry** to exploit their R&D expertise and attract extra funding. The university-industry collaboration exists in a variety of forms, e.g., collaboration in national projects, knowledge transfer, contracted collaboration to develop specific products and standards, and spin-off companies. One noticeable area of strength resulting from the academic and industrial collaboration is fast prototyping of products ranging from amplifier ICs to complete MIMO systems, and from mobile antennas to TD-SCDMA terminals and base stations (BSs).

Chinese universities are undergoing a rapid process of **internationalisation**. A large number of home-educated young faculties have been sent abroad for short visits sponsored by a variety of

national/provincial/university programmes. Meanwhile, many young Chinese researchers who had experience of working and/or studying abroad have been attracted back, especially to those universities situated in major cities such as Beijing and Shanghai. These researchers with global experience have contribute significantly to China's rising levels of international collaboration and the increasing visibility of China's research work in major international journals.

5.2. Industry

Large telecom vendors, such as Huawei and ZTE, have grown to be major international players and have developed comprehensive product lines. Their abilities to export quality products at extremely competitive rates have enabled both companies to grow rapidly despite the global economy downturn. In addition to steady sale growths in the domestic market and emerging markets (e.g., Africa and South America), Huawei and ZTE have started to penetrate the developed markets (e.g., Europe and North America) by forging partnership with leading telecom operators. Market shares suggest that Huawei is becoming predominantly a WCDMA vendor, while ZTE is becoming a leading vendor in TD-SCDMA and CDMA products. The marketing success has allowed both companies to invest huge resource in staff, equipment, and facilities for the R&D of new technologies and standards. Huawei has established 14 R&D centres over the globe.

China Mobile, as a leading **telecom operator,** has become increasingly ambitious in making its footprint on (B)4G R&D and standardisation. Its R&D activities are centralised at the China Mobile Research Institute (CMRI) staffed with 467 employees in the end of 2008. The R&D interest of CMRI spans a wide range from wireless access technologies to networking, terminals, service platforms, and business models. China Mobile is currently rolling out a full-scale TD-SCDMA based 3G network in China. It is also an active advocator of TD-LTE as well as the convergence of TD-LTE and FDD LTE.

Spin off companies, such as Jushri and Starpoint, usually have a top management team coming form Chinese universities or research institutions. They have secured financial support from the government (usually provincial or municipal) and focused on applying their special expertise or advanced technologies to fill the niche domestic markets, such as emergency response communication networks and TD-SCDMA testing products.

Public **research institutions**, such as WiCO and CATR-CTTL, have played a unique role in China's R&D ecosystem. Compared with universities, the Chinese research institutions appear to emphasize less on publications and more on generating patents and standard proposals. Moreover, their researches tend to be more confined and their development activities tend to be closer to real-life products. Mostly sponsored by the government with public funds, the research institutions have become a unique force to bridge the academia and industry.

5.3. Government

4G and B4G, or new generation broadband wireless networks, have been identified by the Chinese government as one of the priority areas that can underpin China's economic and social development. The Chinese government appears to have a clear **vision** in making strategic investments to achieve world-class R&D capabilities in the (B)4G sector. These government investments are strongly focused on major research programmes, key laboratories and top universities. The funding structure ensures that the high-level government vision can be effectively implemented in a top-down fashion.

The MOST of China has funded many major national research programmes such as National High-tech R&D Programme (863 Programme). The most well-known one is the FuTURE project (2000-2010), which has proved to be a huge success in bringing top universities and leading companies in China to push the R&D of B3G systems. In a recently publicised government budget in the period from 2008 to 2020, 70 billion RMB will be invested by the MOST for the R&D of new generation mobile wireless broadband communication networks under the National Key Special Programmes in Science and Technology. Despite these major national projects, the MOST also provides smaller funds to university researchers.

Besides the MOST, the **MIIT and NSFC** also provide significant amount of funding from the central government. Extra funding is also available from the **provincial and municipal governments**.

China's top strategic goal in science is "indigenous innovation". **TD-SCDMA** as the home-grown 3G standard has received and is continuing to receive very strong government support. The Chinese government is very ambitious to make China a major player in global 4G standardisation. It is expected that the Chinese government will give a strong push to **TD-LTE** and/or unified TD-LTE and FDD LTE in its 4G agenda.

Compared to China, the strength of the UK comes from the very productive research system. The wireless communication research community in the UK has been very active and taking a leading position in the (B)4G R&D activities. The original research ideas and fundamental contributions from the UK academics have been published and cited frequently in leading international journals and conference proceedings. The unique linkage between the academia and industry, such as that created by the Mobile VCE, continues to offer very high returns for R&D investment.

All the UK delegation members have been impressed by China's rapid growth after the visit to our Chinese partners. There have been many discussions regarding how to deepen and strengthen the collaboration by securing further funding, especially the funding to UK universities from the UK government, so that the UK does not fall behind.

6. Collaboration Opportunities

During the Beijing workshop, all the UK and China consortium members shared with each other their proposed collaboration topics. This section summarises the collaboration interests of all the partners and provides a preliminary analysis on the overlapping collaboration areas. It is important to note that our future collaboration activities are not limited to the following listed topics, as they are mainly provided for discussion purposes.

6.1. Summary of Proposed Collaboration Topics

Chinese Academic Members:

Beijing University of Post and Telecommunications (BUPT): (1) Capacity analysis of coordinated multi-point (CoMP) transmission network; (2) Capacity analysis of wireless relay networks (3) Capacity analysis of wireless networks for special network environments (e.g., emergency conditions, damaged networks, and high-speed trains)

Huazhong University of Science and Technology (HUST): (1) Interference modelling in MIMO environment; (2) User scheduling and resource management based on cooperative communication in (B)4G; (3) Wireless traffic control and load balancing in cooperative communication system; (4) Wireless frame traffic characterisation and modelling and performance analysis

Shandong University (SDU): (1) Application of MIMO testbed; (2) Cross-layer design and radio resource management; (3) Cognitive radio resource management (RRM)

Southeast University (SEU): (1) Distributed antenna systems; (2) Wireless relays; (3) SON; (4) Interworking of different radio access technologies (RATs); (5) IMT-advanced standardisation; (6) IMT-advanced trial system; (7) Mobility load balancing

Shanghai Jiaotong University (SJTU): (1) Relay communications; (2) CoMP; (3) Cognitive radio networks; (4) Self-organising network (SON)

Tsinghua University (THU): (1) Multiple-AP diversity for interference avoidance; (2) Cooperative diversity in multihop networks; (3) Triple-play network integration; (4) Cross-layer design and radio resource management; (5) Power-efficient new generation networks

Xidian University (XDU): (1) Ad-hoc networks for (B)4G (cooperative); (2) SON for (B)4G; (3) Cognitive networks for (B)4G; (4) Cooperative PMP/Mesh Hybrid Networks for (B)4G; (5) Advanced MIMO Detector in the (B)4G Uplink

Chinese Industry Members:

Shanghai Research Center for Wireless Communications (WiCO): (1) Integrated indoor testing platform; (2) IMT-advanced outdoor trial system

Huawei: (1) MIMO; (2) Cooperative MIMO (CoMP and Relay); (3) Cognitive radio; (4) Interference coordination; (5) RRM; (6) QoS mechanism; (7) Multiple access; (8) FEC; (9) OFDM: soft frequency reuse and carrier aggregation; (10) Green communications

ZTE: (1) Cooperative communications (CoMP and Relay); (2) Cognitive radio; (3) Multi-antenna technology; (4) Joint modulation and coding; (5) RRM; (6) SON; (7) Impact of advanced radio on network architecture; (6) Heterogeneous wireless network; convergence of various networks; multiple radio access technology (RAT) coexistence; (7) QoS provision; (8) Mobility; (9) Random access; (10) Femtocell (home eNodeB)

China Mobile: (1) SON; (2) Femtocell; (3) Relay; (4) CoMP; (5) Collaborative radio; (6) Cognitive radio; (7) Channel measurement and modeling

China Academy of Telecommunications Research *(CATR)*: (1) Green (B)4G test technology and standardisation; (2) R&D on (B)4G testing methods and systems

Jushri: (1) Wide area ubiquitous access: public access plus industry digitalization and emergency communication; high efficiency wireless transmission for triple play and private network; (2) Spectrum usage strategy, spectrum cognition and sharing, especially VHF/UHF band and public safety spectrum

UK Academic Members:

Heriot-Watt University (HWU): (1) MIMO channel modelling, simulation, and measurement for (B)4G; (2) Cognitive radio networks; (3) Cooperative MIMO; (4) Vehicular communication networks; (5) Cross-layer optimisation (radio resource management) of (B)4G wireless networks; (6) (B)4G testbed

University of Edinburgh (UoE): (1) Propagation/channel measurement and modelling; (2) Multihop/Relaying communication and performance analyses (multihop urban) ; (3) Routing protocols for ad hoc/ multihop communication; (4) Sensing and prediction algorithms for cognitive radio (hidden/exposed node problems) ; (5) Interference avoidance/mitigation and radio resource allocation techniques for wireless systems (e.g., femtocell, SON, 60 GHz); (6) Transmitter and receiver designs for MIMO communication; (7) Scheduling and power control techniques for OFDMA/TDD systems and system level performance; analysis (8) Cooperation and load balancing algorithms (e.g., solving the TDD interference problem) ; (9) Indoor positioning and navigation

University of Bristol: (1) Power efficient MIMO techniques for 3GPP LTE and beyond; (2) Car-2-Car communications; (3) Use of location information to improve communications; (4) Power efficient base station hardware

University of Southampton: (1) MIMO; (2) Cooperative communications; (3) Green networking; (4) Multiple access technologies; (5) Channel coding

University of Bedfordshire: (1) Simulation platform for FDD- and TDD- LTE; (2) Femtocells; (3) SON for LTE; (4) Indoor channel modelling and indoor-outdoor radio propagation; (5) Locolisation

University College London (UCL): (1) Differentiated QoS and resilience; (2) Multimedia stream characterisation; (3) Multi-Gbit wireless systems: modulation and coding; spectral- and power-efficiency; (4) Cooperative communications, relay networks and wireless mesh networks; (5) Cognitive radio and dynamic spectrum access; (6) Information theory and cross-layer design and optimisation; (7) Multiuser communications theory; (8) Performance analysis of MIMO-OFDM systems; (9) Heterogeneous and scalable access solutions covering wireless, optical and copper access; (10) Integrated backhaul to support very high bandwidth radio services ; (11) Cross-layer design of access networks; (12) Content adaptation for heterogeneous devices and networks; (13) New infrastructures, topologies and circuits; (14) Service-oriented deployment and management of wireless sensor networks; (15) Optimization for MIMO antenna and relay selection; (16) Antenna Design and Optimisation; (17) RFID and WiFi tracking applications

King's College London (KCL): (1) Green radio; (2) Advanced RRM; (3) Cooperative/relay communications; (4) Advanced multi-antenna systems (CoMP and MU-MIMO); (5) Inter-cell interference coordination

University of York: (1) Self-organising wireless networks (CR, virtual MIMO, network MIMO); (2) Spatial-temporal precoding for (B)4G; (3) Network soft coded modulation

University of Strathclyde: (1) LTE system modelling and characteristics of interfaces; (2) Autonomic Networks – LTE/SON; (3) Wireless sensor networks; (4) Optical-wireless interfaces/interoperability; (5) Context-aware cross layered multimedia streaming based on H.264 AVC/ SVC; (6) Free-viewpoint TV

University of Surrey: (1) Radio environment; (2) Satellite communications; (3) Spectrum and cognitive radio; (4) Next generation networking (SON, cross-layer optimisation); (5) Advanced air interface and receivers (MIMO, cooperative communications, green radio); (6) Service platforms and applications; (7) Internet of things; (8) Content and users

UK Industry Members:

Mobile VCE (MVCE): (1) User interaction for disruptive services; (2) Flexible network; (3) Green radio

BT: (1) Dynamic spectrum access and sharing using cognitive radio; (2) Co-operative multiple antenna cognitive radio and spectrum aggregation

Turner: (1) Service platform; (2) QoS provision; (3) Ad-hoc emergency network

6.2. Analysis of Overlapping Collaboration Topics

In Table 3, we list the proposed collaboration topics of UK and Chinese consortium members which attended the Beijing Workshop. The collaboration topics are classified into 4 technical areas: Antenna and Propagation, Transmission and Radio Access Technologies, Networking Technologies, and Services and Applications. Each technical area consists of several research topics detailed as follows.

Technical Area 1: Antenna and Propagation

1) Channel measurement, characterisation, and modelling
2) Antenna design
3) RF-subsystems

Technical Area 2: Transmission and Radio Access Technologies

4) Cognitive radio (CR)
5) MIMO
6) CoMP
7) Relay communications
8) Green radio (GR)
9) Interference modelling and coordination (IMC)
10) Multiple access (MA)
11) Modulation and channel coding (MCC)

Technical Area 3: Networking Technologies

12) Radio resource management (RRM) and cross-layer design (CLD)
13) Routing
14) QoS
15) Self Organising Network (SON)
16) Mobility Management
17) Location-based communications
18) Traffic engineering
19) Multiple radio access technology (M-RAT) coexistence, heterogeneous networks, and network convergence

Technical Area 4: Services and Applications

20) Vehicular communication networks (VCN)
21) Emergency communications
22) Communications for high-speed trains
23) Femtocell networks
24) Wireless sensor networks (WSN)
25) Testbed, prototype, and software/hardware platform

In the table, organisations are listed horizontally and research topics are listed vertically. An ‘O’ means that the UK partner in the corresponding column has shown collaboration interest in the research topic listed in the corresponding row; a ‘X’ means that the Chinese partner in the corresponding column has shown collaboration interest in the research topic listed in the corresponding row.

From Table 3, we have the following observations.

1. There are many common interests (at least 10 consortium members) in CR, MIMO, CoMP, relay communications, GR, SON, and testbed development.
2. There are a good number of common interests (6-9 consortium members) in channel modelling, IMC, RRM/CLD, QoS, and M-RAT.
3. There are few common interests (less than 6 consortium members) in the rest topics.

Table 3: Overlapping collaboration topics of the UK and Chinese consortium members.

UK	HWU	UoE	Bristol	South.	Bedford	UCL	KCL	York	Strath.	Surrey		MVCE	BT	Turner	
China	BUPT	HUST	SDU	SEU	SJTU	THU	XDU	WiCO	CATR			Huawei	ZTE	China Mobile	Jushri
Technical Area 1: Antenna and Propagation															
1)Channel	O	O			O			X		O		X		X	
2)Antenna						O									
3)RF			O			O									
Technical Area 2: Transmission and Radio Access Technologies															
4)CR	O	O	X		X	O	X	O X		O		O X	OX	X	X
5)MIMO	O	O X	O X	O		O	O X	O X		O		X	OX		
6)CoMP	O X	O X		O X	X	O X	O X	O X		O		X	OX	X	
7)Relay	O X	O X		O X	X	O X	O X	O X		O		X	OX	O X	
8)GR	O	O X	O	O		O X	O		X	O		O X			
9)IMC	O	O X				X	O					X			
10)MA				O		X						X	X		
11)MCC				O		O		O				X	X		
Technical Area 3: Networking Technologies															
12)RRM/CLD	O	O X	X			O X	O					X	X		
13)Routing		O													
14)QoS						O			O	O		X	X	O	
15)SON		O		X	O X		X	O	O	O		O	X	X	
16)Mobility				X					O				X		
17)Location		O	O		O										
18)Traffic		X		X		O									
19)M-RAT				X		O X			O	O			X		X
Technical Area 4: Services and Applications															
20)VCN	O		O												
21)Emergency	X													O	X
22)Train	X														
23)Femtocell		O			O								X	X	
24)WSN						O			O						
25)Testbed	O		O X	X	O			X	O X	O				O	

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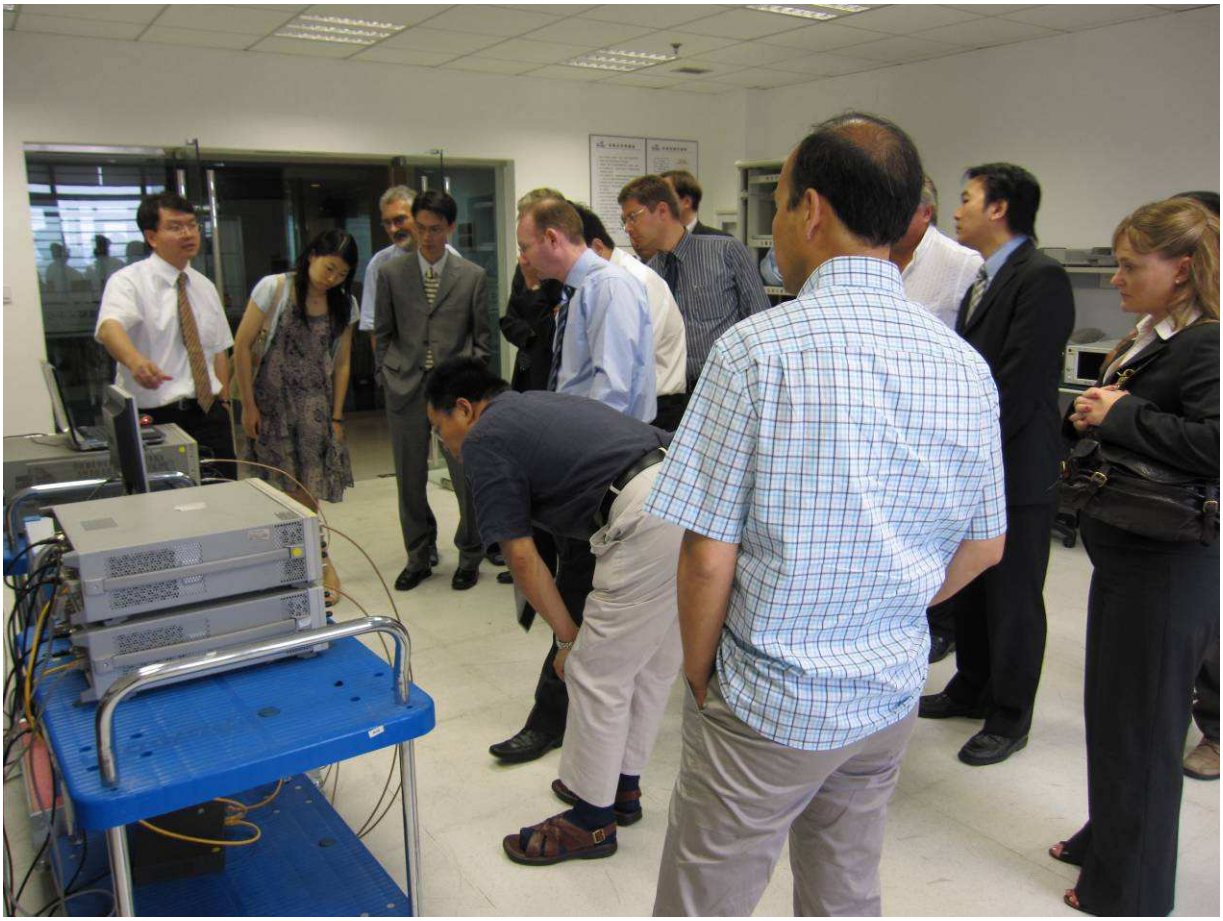
Appendix A: Visiting Reports

A.1. Visit to Shanghai Research Center for Wireless Communications (WiCO)

By Dr Yang Yang (University College London)



Time: 9:30am-1:00pm, Monday 27 July 2009
Venue: Shanghai Research Center for Wireless Communications (WiCO)
6/F, Information Building, 280 Linhong Road, Changning, Shanghai, China

Attendees:

- UK delegation: Dr Cheng-Xiang Wang (Heriot-Watt University), Dr Xuemin Hong (Heriot-Watt University), Dr Siyuan Yu (University of Bristol), Dr Harald Haas (University of Edinburgh), Dr Xiaoli Chu (King's College London), Prof. Lajos Hanzo (University of Southampton), Prof. Ivan Andonovic (University of Strathclyde), Dr Robert Atkinson (University of Strathclyde), Prof. Zhili Sun (University of Surrey), Dr Kai-Kit Wong (University College London), Dr Kenneth Tong (University College London), Dr Yang Yang (University College London), Prof. Alister Burr (University of York), Dr Xuanye Gu (BT), Ms Melanie Stewart (Turner), Mr Simon Fletcher (Telecom MODUS), Sati Bains (ixAssociates), Dr Tian-Hong Loh (National Physical Laboratory), Dr Li-Ke Huang (Aeroflex)
- WiCO: Dr Yong Xiong (Director of R&D Department), Ms Yang Chen (Director for International Collaboration), Dr Honglin Hu (Director of Research Department), Dr Jing Xu (Director for Wireless Standards)

Agenda:

9:30am	The UK delegation arrives at WiCO
9:40am-9:50am	Self-introduction

9:50am-10:05am	Introduction of the UK-China Sciences Bridge project, by Dr. Cheng-Xiang Wang
10:05am-10:20am	Introduction of Mobile VCE, by Simon Fletcher
10:20am-10:40am	Welcome and Introduction of WiCO, by Dr. Yong Xiong
10:40am-11:00am	Tea and Coffee
11:00am-11:20am	Research presentation "Cyclostationary signatures in OFDM-Based Cognitive Radios with Cyclic Delay Diversity", by Dr. Honglin Hu
11:20am-11:40am	Research presentation "B3G/4G Research at WiCO", by Dr. Jing Xu
11:40am-12:30pm	Lab tour, demo and discussions
12:30pm-2:00pm	Lunch

1. Minutes

1.1 Presentation by Dr. Yong Xiong

Shanghai Research Center for Wireless Communications (WiCO) is a non-profit organization co-founded by Chinese Academy of Sciences (CAS), Shanghai Institute of Microsystem and Information Technology (SIMIT), Science and Technology Commission of Shanghai Municipality (STCSM), Southeast University (SEU) and Changning District Government in November 2003. WiCO consists of a group of well-educated and active researchers and is focused on the R&D of the key technologies for future broadband wireless mobile communications. WiCO has successfully undertaken many key research projects from the Ministry of Science and Technology of China (MOST), the National High Technology Research and Development Program of China (863 Program), the European Union Framework Program, CAS, STCSM and telecom industry, covering new air-interface and wireless networking technologies, system integration and performance evaluation, field trials and demonstrations of integrated broadband wireless services, as well as standardization activities at 3GPP and ITU. Through these projects, WiCO has established broad R&D collaborations with many national and international academic and industrial partners in the areas of wireless mobile communications. WiCO has been awarded as the International Center for Wireless Collaborative Research (by MOST), the International Collaboration Base of Science and Technology (by MOST), the Key Laboratory of Wireless Sensor Networks and Communications (by CAS), and the Shanghai Research and Engineering Center for Broadband Wireless Communication Technologies (by STCSM).

1.2. Presentation by Dr. Honglin Hu

The man-induced cyclostationary signatures can provide a robust mechanism for the self-coordination of cognitive radio networks. However, such artificial signatures incur signalling overhead and come at the bandwidth cost. In this talk, Dr. Hu shows intrinsic cyclostaionary signatures in the Orthogonal Frequency Division Multiplexing (OFDM) system with Cyclic Delay Diversity (CDD). The standard conformable CDD technique is initially motivated by the objective for exploiting spatial diversity. The underlying periodicity of CDD can simultaneously induce advantageous cyclostationary signatures without any signalling overhead. The lag-indices of the CDD induced signatures are uniquely determined by the assigned amount of cyclic delay. Consequently each CDD-OFDM system can be identified by a pre-assigned cyclic delay. The signed system can be easily and robustly recognized through cyclostationary detection. Furthermore, the CDD-OFDM systems still preserve the cyclic-prefix induced cyclostationarity as primitive OFDM. By exploiting the overall cyclostationarity, Dr Hu presents a desirable cyclostionarity detector with asymptotical constant false alarm rate for spectrum sensing. Comprehensive simulations are also given to show the performance improvement.

1.3. Presentation by Dr. Jing Xu

In this presentation, Dr. Xu shares his recent work on relay technologies, device-to-device (D2D) communications, and home eNode-B (or Femtocell) for B3G/LTE standards. Some interesting network scenarios and simulation results are shown and discussed.

1.4. Discussions

(1) Prof Lajos Hanzo suggests to consider and prepare joint UK-China research proposals at the national level.
(2) Prof. Ivan Andonovic is very interested in the IMT-Advanced wireless testbed to be integrated and managed at WiCO. He supports the idea of connecting this testbed in Shanghai with the testbed to be developed under this UK-China Science Bridge project at Heriot-Watt University.

(3) Dr. Kai-Kit Wong is interested in Dr. Honglin Hu's presentation on "Cyclostationary signatures in OFDM-Based Cognitive Radios with Cyclic Delay Diversity" and would like to discuss further with Dr. Hu.
(4) Many colleagues are interested in the demo of B3G mobile systems, jointly developed by several leading Chinese universities. The transmission data-rates for uplink and downlink can achieve 75Mbps and 50Mbps by using DFT-S-GMC and OFDMA techniques.
(5) Many colleagues are interested in using the channel emulator EB C8, integrated with ADS system (Agilent) and Matlab, for algorithm development and performance evaluation. It is expected that WiCO will develop a remote control and user-interface by the end of this year for online access and sharing of this advanced research facility.

2. Summary

2.1 (B)4G R&D Activities at WiCO

WiCO aims to become a national-level platform for international cooperation and for system integration, demonstration and verification of research achievements, and to contribute to the inaction of international standards of new generation ((B)4G) mobile communications. WiCO has signed collaboration agreements and conducted joint research with more than 10 world-leading research institutions, universities and telecom companies, such as Nokia, NSN, Ericsson, Huawei, ZTE, Mobile VCE and Prompt, covering a wide range of research topics, such as new air interface technologies, relay, distributed wireless networks, cognitive radio and dynamic spectrum sensing, wireless testbed, system integration, and so on.

2.2 Collaboration opportunities

WiCO researchers have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- Wireless testing environments
- Wireless relay and mesh networks
- Cognitive radio and dynamic spectrum access
- Cross-layer design and optimisation
- Self-organised networks (SON)

3. Contact

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A.2. Visit to Shanghai Jushri Technologies Inc.

By Dr Xuanye Gu (BT)

Time: 14:30-16:30, Monday 27 July 2009
Venue: Conference Room of Shanghai Jushri Technologies Inc.
Attendees:

- UK delegation: Dr C.-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Dr K. Tong (UCL), Dr K. Wong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Mr S. Flectcher (NEC), Prof. S. Yu (Bristol), Dr X. Gu (BT), Dr T. H. Loh (NPL), Mrs M. Stewart (Turner), Prof. I. Andonovic (Strathclyde), Dr. R. Atkinson (Strathclyde), Dr H. Hass (Edinburgh), Mr. S. Bains (IX Associates Ltd), Dr L. K. Huang (Aeroflex Cambridge Ltd)
- Jushri: Dr Zhou Zhigang (Associate Professor, Broadband Wireless Mobile Communications Research Group, Shanghai Institute of Microsystem and Information Technology (SIMIT), Chinese Academy of Science (CA)), plus a group of employees and internship students.

Agenda:

14:30	Arrives at Jushri
14:30-14:40	Self-introduction
14:40-14:50	Introduction of Jushri, by Dr Zhigang Zhou
14:50-15:20	Introduction of the UK-China Sciences Bridge project, by Dr Chengxiang Wang
15:10-15:30	Introduction of Mobile VCE, by Mr Simon Fletcher
15:30-16:30	Lab tour and discussions

1. Minutes

1.1 Presentation by Dr Zhigang Zhou

Dr Zhigang Zhou gave an introduction of Jushri and presented a slides set outlining the formation of the company, R&D, commercial products, investors and collaborations.

1.1.1 Formation of Jushri

Jushri Technologies, Inc is a spin-off company from Shanghai Research Centre for Wireless Communications (SHRCWC, also known as WiCO) and was established in 2006. The main investors are Chinese Academy of Science (CAS), Shanghai Government and SHRCWC.

Jushri is closely connected with SHRCWC, which was established jointly by CAS, Shanghai Municipality, MOST, and Government of Changning District in 2003. SHRCWC's primary R&D areas are next generation broadband wireless communications. Jushri engages projects in National 863 Future Program and participates on international & domestic standardization.

1.1.2 R&D activities

Jushri's R&D activities are primarily wireless transmission techniques and broadband wireless access. The applications of their research and technical activities are divided into the two following major areas.

Broadband Wireless Emergency Communication System

It was noticed that some staff members in Jushri are also belonging to CAS. So Jushri does carry out research from the mid-term to long-term. They also have a technology department that dealt with the industrialization aspects. The company has a sales department in dealing with their clients.

Jushri provides solutions to the video transmission needs for emergency command such as to realize digital video interaction through broadband wireless access network. Such needs can typically serve for emergency situations such as earthquake, or entering an area with a wireless connection need.

Their broadband wireless access systems include wireless backbone communication network, wireless transfer equipment and wireless access equipment. Wireless backbone network provides coverage of a large area (more than 20km). Wireless access equipment is used for receiving and dispatching of data. The wireless transfer equipment is to provide connection between wireless access terminals and wireless backbone communication network.

Their BWA systems are used to cover an area where there can be hot spots, wireless transfer equipment installed on command vehicles, crew equipped with portable digital video cameras and portable wireless terminals, fixed spots or service vehicles installed with fixed or vehicular wireless terminals and video collecting and coding equipment.

Jushri's BWA systems can also be used as an emergency substitute method to extend the coverage of existing networks. The vehicular or fixed wireless terminals can be connected to the backbone network or via command vehicle to complete wireless coverage extension.

Mobile Broadband Wireless Access

Detailed data sheets can be found from the hard copy of technical specifications (Jushri distributed the copy to the UK delegation members)

1.2 Q&A

Dr Haas raised a question about the coverage of 30 sq km and the data rate at the cell edge. Jushri confirmed that the data rate of 2 Mbps was achieved over 30 km at the cell edge. Dr Gu raised three questions. The first question was the spectrum bands used for their systems with their modified WiMAX equipment. Dr Zhou confirmed the bands were within TV White spaces. The second question was about the system trials Jushri conducted to see if there were partners involved. Dr Zhou pointed out that the trials were closely discussed with the local government, the Chinese broadcasting companies/authorities, who take care of the broadcasting bands. The third question was about radio spectrum regulations. The radio spectrum regulation in China is governed by the ministry of industry and information technology (MIIT).

1.3 Dr Chengxiang Wang gave an introduction of the UK-China Sciences Bridge project.

1.4 Mr Simon Fletcher gave an introduction of Mobile VCE and the Green Radio project.

1.5 Lab tour and further discussions

A list of products and solutions are shown during the lab tour, which include circuit board, Base Station equipment and terminals. The equipment displayed during the tour includes vehicular and manned solutions. Outsourcing methods are used mainly for producing circuit cards and boxing the equipment.

Some discussions were taken place about the technologies used for making the chips and circuits. Jushri replied that they own all ASIC techniques for the design stage. Some outsourcing methods are used for producing PCB boards and boxing the equipments.

Some photos were taken during the lab tour, especially for manned solutions. However, the UK-delegation group was advised not to shown these photos in the project website as some equipments main contain some sensitive information.

2. Summary

2.1 (B)4G R&D Activities at Jushri

Jushri has the strong R&D background in broadband wireless access. They collaborate with Nokia, Fujitsu, Ericsson and other organisations in 3G, (B)4G and cooperative communications.
Their systems have shown potentials in commercial opportunities in private network and triple play and have a wide need from the country, though the quantity for supplying these equipments is not necessarily large.

2.2 Collaboration opportunities

During the Beijing workshop, Jushri raised the following topics for collaboration.

2.2.1 Wide Area Ubiquitous Access

- Wide coverage and high data rate
  - Wide area wireless access: Several BS to cover whole city
  - Broadband access: data rate of terminal variable from kbps to Mbps
- Public access plus Industry digitalization and emergency communication
- High efficiency wireless transmission for triple play and private network
  - PHY layer
  - MAC layer

2.2.1 Spectrum Cognitive and sharing

- High efficiency wireless spectrum usage strategy
- Especially VHF/UHF band and public safety spectrum
- Algorithm and implementation
- Evaluation and testing

3. Contact

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A.3. Visit to Huawei Shanghai

By Simon Fletcher (NEC)

Group photo with Huawei Colleagues and UKTI Reps

Time: 10:00-14:00, Thursday 27 July 2009
Venue: Huawei Shanghai
Attendees:

- UK delegation: Mr P. Wills (British Consulate General Shanghai), Ms Amy Zhang (British Consulate General Shanghai), Dr C-X. Wang (HWU), Dr X. Hong (HWU), Dr H. Haas (Edinburgh), Prof. S. Yu (Bristol), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Wong (UCL), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. I. Andonovic (Strathclyde), Dr R. Atkinson (Strathclyde), Prof. Z. Sun (Surrey), Dr X. Gu (BT), Ms M. Stewart (Turner), Mr S. Fletcher (NEC Subsidiary), Dr T. H. Loh (NPL), Mr S. Bains (ixAssociates).
- Huawei: Dr Shugong Xu, Dr Hua Huang, Dr Roy Zhu, Dr Lingqi Li, Dr Ying Gong.

Agenda:

- Overview of Huawei
- Introduction of UK-China Bridge
- Overview of MVCE
- Tour of Product Exhibition Area
- Lunch

1. Minutes

1.1 Overview of Huawei (from Dr Lingqi Li)

The UK delegation is enthusiastically welcomed to Huawei's R&D Centre and the wish is expressed to search for ways to collaborate effectively for long term benefit to all.

With emphasis of the Vision to enrich lives through communication and a Mission that focuses on the Customer. Huawei is still projecting significant growth in sales despite the global financial troubles. There

are now more than 87,000 employees with 37,000 being in R&D. Huawei is organised at 3 levels with the Chinese HQ followed by regional and local.

Ivan seeks clarification about the criteria applied for location of R&D centres. Huang clarifies that the location is driven by talent hot spots. Some UK delegates question why there is not a Huawei R&D centre in the UK. It transpires that investigations are underway to see if a UK R&D centre should be established in 2010. The function of the Basingstoke branch of Huawei is clarified as Sales/Marketing and is branded as a "Mobile innovation centre".

Huawei has been engaged in ~160 collaborative research projects in the past 2 years. Ivan enquires as to the possibility of student placement in the labs in Shanghai. Huawei indicate that at the moment this is not possible as it is unclear how to handle confidentiality issues. This will probably be reviewed in 2010 but there needs to be a clear tangible output and benefit to Huawei.

European Project involvement is still not as high as Huawei would like. Shugong indicates that it is still early days in learning how to engage in these large projects. There have been 6 proposals into FP7 Call4 but only 1 has been successful. Both German and UK government funded projects are also of interest to Huawei. When thinking about the ideal collaborative project model the image Huawei has is of the EU IP projects.

1.2. Presentation by Cheng-Xiang for UK-China bridge project

1.3. Presentation by Simon Fletcher about MVCE (on behalf of Walter Tuttlebee)

Lajos Hanso compliments Simon on the presentation and indicates that it is appreciated by the MVCE Universities to hear strong support for the quality and benefits of MVCE from the Industrial Members.

Hua indicates that WWRF impact would be appreciated. Simon indicates that MVCE Core4 Delivery Efficiency and Core5 Green Radio have attended and run a session at a WWRF event in Paris earlier this year. Hua asks about the approach to IPR Management. SF confirms that IPR is owned by the inventing University and that the Member companies have royalty free access to IPR that was invented at the time that they are members. Companies may not exploit IPR (without royalty fee) that was created before they joined or after they leave.

Hua indicates that it is clear to him that MVCE provides a good platform for collaboration opportunities.

Hua asks about the impact and pull through to Standards. Simon indicates that the Universities are not encouraged within the scope of the Programme to attend and contribute to Standards development as there are generally commercial sensitivities associated with Standards. Universities may spot opportunities and pass on that insight within the Programme. Pull through to Standards is the role of the Industrial partners. Collaboration of Industrial partners to contribute an idea to the Standards is possible, and would typically be handled on a bilateral/adhoc basis.

Hua asks if there may be expected to be Future Internet impact from the Flexible Networks Programme. Simon indicates that he hopes so as this is certainly an area that requires some innovative ideas. Prof. Z. Sun indicates that several of the MVCE Universities, including the University of Surrey, are actively involved in research into the Future Internet.

1.3. Tour of the Product Exhibition Area

The UK delegation is given a tour of the Product exhibition area. The delegation sees the latest product lines in LTE, WCDMA, WiMAX, and CDMA. There are several examples of multiple Standard platforms on display including Radio Base Stations and Remote Radio Heads. There are also examples of WiMAX femtocell and core network solutions with emphasis on enabling the Fixed Mobile Convergence story.

1.4. Lunch

Lunch hosted by Huawei at a local restaurant is enjoyed and appreciated by all.

2. Contact

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A.4. Visit to Shanghai Jiao Tong University (SJTU)

By Dr. Xiaoli Chu (King's College London)

Time: 14:45-17:30, Tuesday 28 July 2009
Venue: Meeting Room, Department of Electronic Engineering (EE), SJTU
Exhibition Hall of SJTU
Shanghai Key Laboratory of Digital Media Processing and Transmissions, SJTU
Attendees:

- UK delegation: Mr P. Wills (British Consulate General Shanghai), Ms Amy Zhang (British Consulate General Shanghai), Dr C-X. Wang (HWU), Dr X. Hong (HWU), Dr H. Haas (Edinburgh), Prof. S. Yu (Bristol), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Wong (UCL), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. I. Andonovic (Strathclyde), Dr R. Atkinson (Strathclyde), Prof. Z. Sun (Surrey), Dr X. Gu (BT), Ms M. Stewart (Turner), Mr S. Fletcher (NEC Subsidiary), Dr T. H. Loh (NPL), Mr S. Bains (ixAssociates). Dr X. Wang (Swanmesh); Dr P. Loskot (Swansea).
- SJTU: Prof. Jianping Chen (HoD of EE), Prof. Ronghong Jin (Deputy HoD of EE), Prof. Youyun Xu (Head of IWCT), Associate Prof. Lin Gui, Associate Prof. Liang Qian, Associate Prof. Meixia Tao, Associate Prof. Xinbing Wang, Dr Jing Liu, Dr Xiaoying Gan, Dr Daorong Xu.
- Zhejiang University: Prof. Honggang Zhang

Agenda:

14:45-15:00	Exchange of business cards and self-introduction around the table
15:00-15:15	A video introduction of SJTU (history, development, international collaborations, etc.)
15:15-15:25	Welcome speech by Prof. Jianping Chen (Head of Dept. of Electronic Engineering, SJTU), including an introduction of the EE Department
15:25-15:40	Introduction of the Institute of Wireless Communication Technology (IWCT) at SJTU by Prof. Youyun Xu (Head of IWCT)
15:40-16:05	Introduction of the UK-China Science Bridges project by Dr Cheng-Xiang Wang
16:05-16:15	Introduction of Mobile VCE by Mr Simon Fletcher
16:15-16:40	Discussions on possible collaborations
16:40-17:00	Visit the Exhibition Hall of SJTU
17:00-17:30	Visit Shanghai Key Laboratory of Digital Media Processing and Transmissions at SJTU
18:00-20:00	Dinner at SJTU

1. Minutes

1.1 Welcome Speech

Prof. Jianping Chen, HoD of EE, SJTU, gave a welcome speech and an introduction of the EE Department, which covered the labs and research centres within EE, including joint labs with Microsoft, Taxes Instruments, and IBM. The introduction also covered projects and results, awards (2001-2008), achievements in national key projects, e.g., 3TNet (backbone test-bed), mobile video communications, national standards for wireless transmission of digital TV signals, and international interactions and exchanges.

1.2 Introduction of IWCT at SJTU by Prof. Youyun Xu

1.2.1 "Introduction of IWCT"(Summary of key points of the presentation)

Prof. Xu's presentation introduced major achievements of IWCT in publications, patents, projects, and number of faculty members. The major research areas of IWCT include digital mobile cellular communications (B3G, OFDMA systems, multihop relay networks, TD-LTE, IMT-Advanced, etc.), digital broadcast systems (DVB-T, handset mobile TV, GPS broadcast systems, etc.) and wireless body-area networks. IWCT has established many collaboration links with industrial partners. The students are very active in the in-house R&D as well as international electronic design competitions.

1.3 Introduction of the UK-China Science Bridges Project by DrCheng-Xiang Wang

1.3.1 Q&A

1) Prof. Youyun Xu (SJTU) asked about the funding situation for Chinese partners on the project. Dr Cheng-Xiang Wang answered that in WP2 about 15 Chinese academic researchers will be funded to visit UK universities for up to 3 months. In WP3 about 20 Chinese researchers will be funded to attend two international workshops organised in the UC4G project.

2) Prof. Honggang Zhang (Zhejiang Univ.) asked about the possibility of involving Zhejiang University and Swansea University in the project. Dr Cheng-Xiang Wang explained the partnership agreement of the project and indicated that accepting new members into the collaboration network is possible but need to be discussed and approved by the project management committee (PMC).

1.4 Discussions on Possible Collaborations

1) Prof. Lajos Hanzo (Southampton) suggested starting a more technical discussion. Dr. Cheng-Xiang Wang (HWU) mentioned that the workshop in Beijing would be more appropriate for detailed idea exchange for research collaborations.

2) Dr. Harald Haas (Edinburgh) asked SJTU faculty members to introduce more about on-going research activities and future plans. Prof. Youyun Xu (SJTU) briefly introduced current research activities within IWCT. Prof. Meixia Tao (SJTU) talked about national key projects at IWCT related to LTE, LET-Advanced, IMT-Advanced, relay technologies, and cognitive radio.

3) Prof. Lajos Hanzo (Southampton) commented on some unsolved issues in 4G PHY technologies and related standardizations.

4) Prof. Liang Qian (SJTU) asked about the roles played by industrial and academic partners in the project, respectively. Prof. Lajos Hanzo (Southampton) briefly defined such roles. Dr Cheng-Xiang Wang (HWU) explained the aims and objectives of the project, the agreement to be signed by all partners, and functions of future work packages.

1.5 Visit Shanghai Key Laboratory of Digital Media Processing and Transmissions at SJTU

Prof. Liang Qian (SJTU) gave a presentation about the on-going development of a 4G test-bed and the testing environment on SJTU campus. Dr. Harald Haas (Edinburgh) asked about the specific characteristics of the test-bed at SJTU, as compared with test-beds built by WiCO, Jushri, and Huawei in Shanghai. Prof. Liang Qian said that the test-bed developed at SJTU is relatively more research-oriented.

2. Summary

2.1 (B)4G R&D Activities within IWCT at SJTU

The IWCT at SJTU has been carrying out research activities in many aspects of (B)4G radio access networks, ranging from digital cellular communications and digital broadcast systems to industry-ready prototype data access wireless networks and solutions for special wireless scenarios. 70% of projects within IWCT are sponsored by NSF, 863, 973, and Key Special Subjects (KSS); 30% of projects are supported by industry. IWCT is a major contributor to the China B3G/4G FDD mode 20Mbps trial system (2001-2003) and China B3G/4G TDD mode 100Mbps trial system (2003-2006). IWCT has been participating in IMT-Advanced research and evaluation since 2006.

2.2 Collaboration Opportunities

SJTU faculty members have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- Relay, e.g., OFDMA-based multihop relay networks
- Coordinated multi-point (CoMP) communications
- Cognitive radio and networks
- Self-organising networks (SON)

3. Contact

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A.5. Visit to Southeast University (SEU)

By Dr Kai-Kit Wong (University College London)

Time: 14:30-18:00, Wednesday 29 Jul 2009
Venue: Conference Meeting Room, Engineering Building, SEU
National Mobile Communications Research Laboratory (NMCRL), SEU
Attendees:

- UK delegation: Dr C.-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr Y. Yang (UCL), Dr K. Wong (UCL), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. I. Andonvic (Strathclyde), Dr R. Atkinson (Strathclyde), Dr H. Haas (Edinburgh), Prof. Z. Sun (Surrey), Prof. S. Yu (Bristol), Mr S. Fletcher (M-VCE), Dr X. Gu (BT), Dr T. H. Loh (NPL), Ms M. Stewart (Turner), Mr S. Bains (ixAssociates).
- SEU delegation: Prof. Xiao-Hu You (Director of NMCRL and Director of WiCO), Prof. Xiqi Gao, Prof. Zhiwen Pan, Prof. Nan Liu.

Agenda:

14:30-14:50	Self-Introduction
14:50-15:40	Presentation by Prof. Xiaohu You
15:40-16:00	Introduction of the Science Bridge Project by Dr Cheng-Xiang Wang
16:00-16:20	Introduction of Mobile VCE by Simon Fletcher
16:20-17:20	Lab tour
17:20-18:00	Further discussions
18:00-20:00	Dinner

1. Minutes

1.1 Self-Introduction Session

Prof. You (SEU) first introduced the members of SEU participating in the meeting. Then, every UK delegate briefly introduced him/herself with a brief description of research interests and activities at the representing institutions.

You (SEU) then gave a talk introducing their laboratories and their research activities on (B)4G.

1.2. Presentation by Prof. You (SEU)

*1.2.1 "**An Introduction to National Mobile Communications Research Laboratory**"*

The lab was founded in 1989 and approved by the State Planning Commission and the Ministry of Education (MOE). The lab also received 1.2M USD financial support and was specifically supported by the "211" and "985" projects of the MOE – the national key discipline development projects. NMCRL is equipped with modern R&D facilities, including EDA tools and mobile communication specific measurement instruments. The Lab's mission is to promote the basic knowledge for mobile & wireless communications, provide up-to-date training for university graduates and professional visitors and transfer the know-how to the industries. Currently, it has 17 professors, 58 faculty members, 12 post doctoral researchers, 18 visiting scholars and guest researchers and 380 graduate students, including 80 Ph.D. students. Just in the year 2007 alone, the total funding received was about 44.9M RMB, 90% of which came from the Chinese government. The presentation also gave a very good overview of some ongoing research activities on (B)4G systems.

1.2.2 Q&A During the Talk:

1) Prof. Hanzo (Southampton) asked if the figures on the slide regarding the numbers of members reflect only those in the communications group and this was confirmed by Prof. You (SEU).

2) Prof. Andonvic (Strathclyde) asked who funds the testbed activities at SEU and Prof. You (SEU) clarified that it is the Chinese Government funding the activities.

3) Dr. Tong (UCL) wanted to know the frequency of the fibres underneath the radio networks and Prof. You (SEU) replied that the frequency on the fibre is 1GHz and the carrier frequency is 3.5GHz.

4) Dr. Wong (UCL) had a question on how to decide the locations of the base stations on the distributed antenna systems (DASs) and Prof. You (SEU) commented that the base stations should be placed as evenly as possible over the area.

5) Dr. Haas (Edinburgh) asked if the frequency reuse factor is 1 in the DAS systems and Prof. You (SEU) confirmed that this is the case.

6) Dr. Xu (BT) asked that for the 8x4 and 4x4 MIMO systems, how many antennas are at the mobile terminals. Prof. You (SEU) then clarified that there are 4 antennas at the mobile terminals.

7) Dr. Haas (Edinburgh) had a concern on the synchronization issues of DAS but Prof. You (SEU) explained that this is not a serious problem because the delay for optical fibre is fixed and very consistent. Therefore, this can be mitigated fairly easily and effectively.

8) Dr. Wang (HWU) questioned how the transmission is done with frequency reuse factor of 1 and Prof. You (SEU) said the system is operated like a multiuser MIMO system.

1.2.3 Q&A After the Talk:

1) Dr. Loh (NPL) asked to clarify the meaning of the position numbers on the slides and Prof. You (SEU) showed the diagram of the DAS and clarified that the position number is the index for the discrete positions on a specific path where the trial was run.

2) Mr. Bains (ixAssociates.com) was interested to know if the base stations are fixed in the testbed and Prof. You (SEU) replied that the base stations are fixed.

3) Prof. Burr (York) was interested to know what environments were considered. In particular, were there many high buildings and also wondered if there exists line-of-sight (LoS) in the environment. Prof. You

(SEU) clarified that there were many high buildings but as the antennas are put at the roof top of the buildings, mostly they do have LoS.

4) Mr. Bains (ixAssociates.com) asked if the trial has been conducted in the environment without LoS. Prof. You (SEU) replied and commented that for the case with LoS as compared to that without LoS, the difference would be on the number of activated data streams.

5) Dr. Haas (Edinburgh) asked for a clarification on the channel models on DAS and co-located antenna systems (CASs). Prof. You (SEU) said that flat Rayleigh fading with shadowing is used in the analysis.

6) Prof. Yu (Bristol) pointed out that due to the importance of saving energy, costs should be added to customers for reducing their transmit power. Prof. You (SEU) feels that this makes very good sense.

7) Prof. Zhang (Bedfordshire) commented that the antennas in DAS should not be placed at the roof tops of the buildings because this will cause severe interference problems and Prof. You (SEU) agreed with that.

8) Dr Tong (UCL) also commented that reducing the sizes of cells could provide better coverage, which was agreed by Prof. You (SEU).

9) Dr. Wang (HWU) wondered if the channels are considered to be uncorrelated and Prof. You (SEU) replied that for the theoretical analysis, uncorrelated channels were considered while for the trials, obviously, this was not the case. Prof. You (SEU) then added that some more details of the DAS can be found in their IEEE Transactions on Signal Processing (TSP) paper in May 2008.

10) Dr. Hong (HWU) had a question on the slides regarding the capacity results of DAS and wondered why the results are conditioned on the mobile terminal's location. Prof. You (SEU) then explained that instantaneous capacity is considered, so it depends on the channel which also depends on the mobile terminal's location. However, the capacity result is also then averaged over space (the mobile terminal's location) to provide an indicator for the average system performance.

11) Prof. Hanzo (Southampton) asked whether we could have the slides for the talk. Prof. You (SEU) has kindly agreed to let us have the slides.

12) Prof. Andonvic (Strathclyde) asked if it is possible to make the slides accessible on the project website and CXW (HWU) then kindly confirmed that this will be done.

1.3 Presentation by Dr. Wang (HWU)

*1.3.1 "**UK-China Science Bridges: R&D on (B)4G Wireless Mobile Communications**"*

1.3.2 Q&A During and After the Talk

1) Prof. Yu (Bristol) asked whether the slides will be made publicly available for people other than the consortium. Then, Dr. Wang (HWU) relied that at the moment, they are made public. Then, Prof. Andonvic (Strathclyde) raised an issue that because of the MOU we signed, perhaps it makes more sense to make the slides available only to the consortium members. Dr. Wang (HWU) agreed that this is a valid point.

2) Prof. You (SEU) asked if (B)4G trial is considered as one of the work packages of the project and Dr. Wang (HWU) confirmed that this will be the case. Then, Dr. Wang (HWU) went on to point out that China has a number of (B)4G trial networks that may be of great use in this aspect. Prof. Andonvic (Strathclyde) then followed up and asked if it is possible to ship the trial equipments from China to UK for use and then ship them back to China after use. Prof. You (SEU) said no and explained why this was not possible.

3) Dr. Wang (HWU) asked if there are any plans to build more (B)4G trial networks. Prof. You (SEU) replied that there will be another project for that in the next year and is expected to last till 2012.

4) Dr. Haas (Edinburgh) asked if the systems in China are TDD or FDD based. Prof. You (SEU) said that the system supports both. Dr. Haas (Edinburgh) went on and asked which one is better. He also commented that

feedback is important to make MIMO work effectively. In this respect, TDD may be more advantageous. Prof. You (SEU) responded that so far it is not entirely clear which one is better. For IMT advanced, this is still in preparation and should have a decision on whether TDD or FDD is being put forward in the near future. Dr. Haas (Edinburgh) was also interested to know if the TDD feature was exploited in the system. Prof. You (SEU) commented that Prof. Gao (SEU) has done lots of fundamental works for that.

5) Following on this in-depth discussion on TDD versus FDD, Prof. Hanzo (Southampton) added that under light user load scenarios, both TDD and FDD work, but when the user load is high and if TDD is not properly scheduled, interference comes in and problem arises.

6) Dr. Haas (Edinburgh) also added that TDD has the flexibility to adapt the switching point (between the UL and DL) in accordance with user loading. Prof. Hanzo (Southampton) then pointed out that in practice, there are other factors such as latency, etc that make the problems very difficult to quantify and it is not that simple to see which duplexing mode is better.

7) Dr. Xu (BT) asked to clarify if the CSI that is exploited at the transmitter for MIMO is partial or full. Prof. Gao (SEU) confirmed that it is statistical CSI, so it's partial but not full CSI. Dr. Xu (BT) then had a question on whether space-time coding (STC) is used at the transmitter and this is confirmed by Prof. Gao (SEU). Dr. Xu (BT) then commented that if STC is used, then there should not be much problem of interference. Prof. You (SEU) also added that the precoding matrix is specifically designed according to the statistical CSI. Therefore, the interference is controlled. Prof. Gao (SEU) then also pointed out that the number of data streams is also adapted in the system, just like CDD (cyclic delay diversity) systems and it works.

1.4. Presentation by Mr. Fletcher (NEC & M-VCE)

1.4.2 Q&A During and After the Talk

1) Prof. You (SEU) was interested to know the ownership of the patents developed from the MVCE funded projects. Dr. Fletcher (MVCE) explained that the way it works is that the university owns the patent but the members in MVCE are free to exploit the patent. Prof. Hanzo (Southampton) then added and gave an example to explain further how this works within MVCE.

2) Prof. You (SEU) then asked if he can have a list of projects funded by MVCE. Dr. Fletcher (MVCE) kindly agreed to send him a link where it has the information for the funded projects.

3) Prof. Hanzo (Southampton) then added and shared his past experience with MVCE. He was running the work package 1 of the physical layer research looking into pros and cons of IDMA (interleave-division multiple-access), the benefits of using CSI at the transmitter, also how to deliver the estimated CSI and specifically how many pilots are needed to estimate the CSI sufficiently accurately. It turned out that it depends on how fast the channel is changing. He also did lots of works on DAS and looked into decoder design such as sphere decoder. In addition, he was also involved in cooperative communications research. Also, with Surrey, they developed differential encoding and adaptive modulation and power control in computer networks. Also, he has two more students working on network layer, cross layer optimization and many more.

1.5 Lab tour

Prof. You (SEU) showed the UK delegate members around and showed some testbeds (indoor as well as outdoor testbeds). The demonstration included a prototype of 6x4 MIMO TDD base station and mobile terminal. The bandwidth used is 100MHz achieving 1Gbps. Also, it was based on China WiMax OFDM/GMC systems. Another demonstration was a FDD system with double turbo STC and adaptive modulation which is an outcome of the FuTURE project. SEU mentioned that they also tried LDPC codes but the complexity increases with no substantial gain.

Regarding the issue of LDPC, Prof. Hanzo (Southampton) commented that it depends on the "activation range". Basically, the iterations for the first code should not be overdone because it may limit the degrees of freedom of the second code for error correction. Therefore, it is of interest to optimize the number of iterations for the decoders in the turbo process given the amount of affordable complexity.

Then, we moved to visit the State Key Laboratory of milli-meterwave and saw various antenna designs such as those for beam diversity MIMO systems.

1.6 Further discussions after the tour

After the lab tour, we went back to the conference room for a more extensive Q&A session where we exchanged our opinions on (B)4G and discussed various important issues for wireless communications networks.

1) Prof. You (SEU) shared his views on the FuTURE project and towards B3G. He explained that the 1st phase is led by universities while during the 2nd phase, the ultimate goals are standardization and testbed for (B)4G. For the standardization, they will work on proposals and send them to ITU in early October this year. Prof. You (SEU) added that tomorrow, he will discuss this with Huawei but initial consideration is that DAS will be used fully in both base stations and antennas. He believes that DAS will work for B4G. On the other hand, he anticipated that a trial system for 4G will be underway in the next 4-5 years. In this area, of course, industries will lead given their expertise and knowhow.

2) In addition, Prof. You (SEU) commented that relay could be an attractive solution to cell edge problems for LTE. Also, he believes multiuser MIMO is important here as well.

3) Dr. Wang (HWU) expressed an interest to know Prof. You (SEU)'s view on cognitive radio technologies. Prof. You (SEU) responded that they actually tried to exploit the white spaces of UHF band, but it's extremely complicated because this issue is very sensitive to the communities of TV and mobile communications and therefore controversial. He added that perhaps, to start with, cognitive radio can be used for short range communications.

4) Dr. Wang (HWU) also pointed out that there seems to have different 3G systems and asked will there be converging to simple one 3G system eventually. Prof. You (SEU) then expressed his views on this and believes that it will be only one in the end.

5) The discussion then was moved to the networking aspects of mobile communications systems. Prof. You (SEU) and Prof. Hanzo (Southampton) commented that perhaps we should move away from the all-IP network architecture. Prof. Andonvic (Strathclyde) commented that it may be useful to consider layered network architecture where it would be possible to isolate the complexity growth of the networks and this idea was highly appreciated by Prof. You (SEU). Prof. Andonvic (Strathclyde) also pointed out that legacy is the main problem and therefore we should take incremental steps to achieve a significant change.

6) In addition, Prof. You (SEU) commented that DAS is an attractive solution for saving power or green radio. Particularly, for RF, we could consider more efficient power amplifiers and in the future, perhaps, we should not use high-level QAM because it is not energy efficient.

7) Prof. Yu (Bristol) made a comment that the research councils in the UK tend to respond to external arguments and that seems to be what has always happened because the local discussion between UK academics and the research councils has not been responded.

8) Prof. Sun (Surrey) on the other hand commented that there are two main challenges for satellite communications. The first one is antenna size and the second one is power.

9) Prof. You (SEU) then asked the UK delegate members about the financial support in the UK for communications research.

10) Prof. Yu (Bristol) replied that ICT actually got quite a big chunk of funding but communications research is not much supported within ICT. Dr. Wang (HWU) added that we have EPSRC in the UK and this is the NSF equivalent in China. Prof. Hanzo (Southampton) also added that he attended the town meeting in London. The chairs of communications research expressed the problem of weak support from EPSRC but the conclusion was that engineers tend to be so much more critical than the computer scientists, which to some extent explains why the computer science research gets more support than the communications research within ICT from EPSRC.

11) Dr. Haas (Edinburgh) was interested to know what sort of support is received from the china government for the two spin-off companies. Prof. You (SEU) explained that the IP will go to the companies and the university gets some of the shares of the companies. Dr. Hass then asked if it is easy to set up a company in China and the answer was no.

12) Later, Prof. Sun (Surrey) was interested to know where the turnovers and revenues go to. Prof. You (SEU) replied that roughly speaking each person spent about RMB200k-300k a year. Prof. Sun (Surrey) then added that in the UK, their company started with £5m and they sold off at £50m.

2. Summary

2.1 (B)4G R&D Activities at SEU

The NMCRL of SEU is one of the greatest contributors to the research activities of future-generation wireless communications systems in China. Their great efforts on the FuTURE demonstrator and DAS systems are well known examples. Their research activities cover both applied and curiosity-driven fundamental researches that range from advanced DSP to broadband wireless networks and systems.

2.2 Collaboration opportunities

SEU have indicated the following research areas for future collaboration with the UK partners:

- Multiuser MIMO communications
- Cooperative and relay communications
- Antenna design for broadband communications
- Radio-over-Fibre networks

3. Contact

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A.6. Visit to Huazhong University of Science and Technology (HUST)

By Dr Kenneth Tong (UCL) and Dr Robert Atkinson (Strathclyde)

Time: 14:50-18:05, Thursday 30th July 2009
Venue: Department of Electronics and Information Engineering, HUST
Wuhan National Laboratory for Optoelectronics
Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Mr S. Fletcher (M-VCE), Dr X. Gu (BT), Dr T. H. Loh (NPL), Prof. I. Andonovic (Strathclyde), Dr R. Atkinson (Strathclyde), Mr S. BAINS (ixAssociates), Ms M. Stewart (Turner), Prof. S. Yu (Bristol), Dr Henry Wang (Swanmesh).
- HUST: Prof. Youmei Feng (Vice President of HUST), Prof. Guangxi Zhu (Chair of Academic Committee of E & I Dept, HUST), Prof. Yingzhuang Liu, Dr Xiaohu Ge, Dr Wei Liu, Dr Wei Yuan, Dr Guan So, Dr Shu Wang.

Agenda:

14:50-15:00	Poster presentation of the Mobile Communications Group, by Dr Guan So
15:00-15:15	Introduction of HUST and WNLO, by Prof. Guangxi Zhu and Prof Yingzhuang Liu
15:15-15:20	Demonstrations of the PSMA broadband wireless access system and Broadband Wireless Based AVS Intelligent Video Surveillance system, by Dr. Guan So
15:20-15:40	Open discussion
15:50-16:00	Introduction of Department of Electronics and Information Engineering, by Dr. Xiaohu Ge
16:15-16:35	Wireless and Network Lab tour
16:35-16:45	Welcome speech from the Wireless and Network Lab by Prof Wei Yuan
16:45-17:20	Presentation of the research in HUST by Dr. Xiaohu Ge
17:20-17:45	Introduction of the UC4G Science Bridge project, by Dr C-X. Wang (HWU)
17:45-18:05	Introduction of M-VCE, by Mr S. Fletcher
18:05-20:00	Dinner

1. Minutes

1.1. Poster Presentation by Dr Guan So

The posters presented included:

- Beyond 3G-TDD system general architecture (863 National Project Scheme)
- Seamless vertical handover in heterogeneous wireless network
- Channel coding in broadband wireless communication – A project makes used of Turbo Coding to improve QoS and based on 802.11 WiFi technology. A demonstration which include a basestation and mobile unit has been preformed.
- Research on standard for broadband wireless metropolitan network IEEE 802.16
- Research of the encoding and decoding algorithm of low density parity check codes.
- AVS (National 864 project), the system based on mpeg 2. 42 patents have been submitted in 8 years.
- Multimedia processing and system application with optical-electronic synchronized technology.

1.2. Meeting with the Mobile Communications Group

First, Prof Guangxi Zhu, the director of the key lab, welcomed the UK delegation and invited Prof Yingzhuang Liu to gave a general presentation on HUST and WNLO (Wuhan National Laboratory for Optoelectronics) which included their

- Project themes
- Research groups
- Research projects which include internal and collaboration with industries
- Key Patent Technologies
    - New IP-Based Broadband mobile multimedia Communication Technology.
    - PDMA experiment network
    - BWA Product
    - LAS CDMA Cellular
    - B3G Phase II experiment work

Q&A

Dr Cheng-Xiang Wang (UK) raised the discussion between FDD-B3G and TDD-B3G. Prof Zhu gave a brief introduction of the B3G projects in China. Prof Zhu just came back from a meeting in Beijing about 34 mobile communication projects in China, 8 of the projects about radio resource management are proposed by HUST.

Prof Lojas Hanzo (UK) asked for the detail about the 8 projects. Prof Zhu explained that the projects are about IMT advanced wireless resource management research and validation.

Prof Yingzhuang Liu further elaborated that they have proposed some new standards and a new test-bed will be built. It is a 3-year projects which have just start. The total budget is about 5M RMB from the Ministry of Industry and Technology.

Dr Cheng-Xiang Wang (UK) asked for the differences between the test-beds will be built by a few different universities, as the delegation has noticed that a number of test-beds have been planned to build in universities / companies in China. Prof Liu explained the test-bed will be built based on their research aims. Their partners include Beijing Jian Tong University, WiCo, FiberHome (company).

Prof Ivan Andonovic (UK) asked if it is possible to combine all these test-beds. Prof Liu answered all the test-beds in China are self-content. The team will develop their own RF and baseband, and their test-bed will be focused on resource management. Prof Zhu said some projects they worked with industries and some with other universities such as UESTC (University of Electronic Science and Technology of China).

1.3 Lab Tour

The wireless RFID system which consisted an ID reader, a transmitter and server have been demonstrated. A PhD student has showed the delegation their projects in VoIP, embedded devices, wireless streaming server.

Q&A

Prof Andonovic asked the student the data rate of the system and if it performed any compression. The answer was 2Mbps. Dr Henry Wang (UK) asked how many cameras could be supported and the delay. The student replied 13 and the delay is small. Dr Wang further asked how long the team has developed the system. The reply was 1 year. The student has also explained the system ran on Linux platform. More questions about the detail of the streaming system such as its performance were also asked.

Dr. Shu Wang presented their team which included:

- Research Field
- Research Projects
- Automatic Fire Alarm System based on WSN and key problems of the projects presented. The group thought cognitive radio network would be the key wireless technology for WSN.
- WSN bases on Zigbee/IEEE802.15.4
- Zigbee Localization System chip CC2431

Prof Ivan Andonovic asked if they have investigated in multi-agent and AI system.Prof Shu replied the algorithm included some AI theory. Prof Andonovic questioned what / how the algorithm does? Prof Shu answered the algorithm is based on single node, no cooperation between nodes. It is only node to server. And server reports the fire.

A student from HSUT demonstrated how the WSN works. And the smoke detector was triggered by the generated smoke. After two more temporary and one movable nodes were introduced. The location of the movable node was successfully detected.

Prof Andonovic asked what the performance is in the case of more than one movable node. Dr Kenneth Tong (UK) asked what other sensors they have developed. Prof Shu replied they also developed a passive RFID system and a video streaming system.

1.4. Presentation by Dr Xiaohu Ge

Prof Xiaohu Ge gave a presentation of HUST about their research in:

- (B)4G mobile communication
- Interference coordination in MIMO communication and Capacity management.
- Cognitive radio and sensor networks
- Localisation and self-organisation technology for WSN
- Capacity analysis in mulit-cells MIMO communication
- Traffic balance in multi-cells based on cooperation communication
- User scheduling in multi-cells MIMI communication

Q&A

Dr Kit Wong (UK) was interested in their research in MIMO and WSN. Prof Wei Lu explained the Virtual MIMO WSN was a small project started in 2006 and has already been finished. Some journal papers were published based on the results from the project. Dr Wong further his question about the objectives of the virtual MIMO WSN.

Dr Henry Wang (UK) asked if the team has done any work in space and sky information network. The answer was no.

Dr Cheng-Xiang Wang (UK) asked the group about their projects in cognitive radio network. Prof Liu Wai answered that their work in cognitive radio started from 2007, mainly in the MAC layer, resources analysis and applying game theory for information sharing to maximize the throughput of the network. The work has been published in several papers. Other work in the network layer of cognitive radio was also done.

Dr Cheng-Xiang Wang (UK) asked if the group would collaborated with other universities in cognitive radio, such as BUPT. Prof Liu replied that it was difficult to do so.

Dr Xuemin Hong (UK) asked if there is any working cognitive radio network in China. Prof Liu said there was one in china at the moment.

1.5 Presentation by Dr. Cheng-Xiang Wang

Dr Cheng-Xiang Wang (UK) gave a presentation of the UK-China Science Bridges project.

Q&A

Prof Zhu asked if the funding was in place, and supported any Chinese researchers. Dr Wang explained the funding will support about 15 Chinese academic members to visit UK for long term sustainable research; moreover the funding will support 20 Chinese researchers to attend conferences.

Prof Liu asked how the research outcome from the UK-China SB projects would be transformed into demonstrations or even product. Dr Wang explained that in WP5, the project tried to attract the industry to get involved into the project. The format of collaboration has not been fixed. The panel members will monitor the progress and find the best way to achieve so. They hope there will be involvement of the industry after WP4. Prof Lajos Hanzo expressed his understanding to Dr Liu's concerns about the industry partner, and he agreed that it is important to commercialize the research outcome. Dr Wang continue to explain that he wanted to show the industry to value and the output of the project and hope they will invest more money after.

2. Contact

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A.7. Visit to Xidian University (XDU)

By Prof. Jie Zhang (University of Bedfordshire) and Dr Xiaoli Chu (KCL)

Time: 15:30-18:30, Friday 30 July 2009
Venue: State Key Laboratory of Integrated Service Network (ISN), XDU
Attendees:

- UK delegation: Chengxiang Wang (CXW), Ivon Andonovic (IA), Siyuan Yu (SY), Lajos Hanzo (LH), Alister Burr (AB), Xiaoli Chu, Xuanye Gu, Robert Atkinson, Simon Fletcher (SF), Tian Hong Loh (THL), Sati Bains, Kit Wong, Zhili Sun, Harald Hass (HH), Kin Fai (Kenneth) Tong, Melanie Stewart, Xuemin Hong, Jie Zhang (JZ)
- XDU: Profs. Jiandong Li (JDL), Hailin Zhang (HLZ), Kechu Yi (KCY), Jianhua Ge (JHG), Min Sheng (MS), Liqiang Zhao (LQZ), and Xinbo Gao (XBG, Dept. of International Relations), and PhD and master students, etc.

Agenda:

15:20-15:40	Welcome reception and self-introduction
15:40-15:50	Welcome speech and introduction of XDU, by Prof. Xinbo Gao
15:50-16:10	Introduction of the School of Telecommunications Engineering, by Prof. Hailin Zhang (the Dean of the School of Telecommunication Engineering)
16:10-16:30	Introduction of the State Key Lab of ISN, by Prof. Jiandong Li (head of the state key lab of ISN)
16:30-16:50	Introduction of the Mobile VCE by Simon Fletcher
16:50-17:00	SDU staffs and the UK delegation take photos
17:00-17:20	Introduction of the UK-China Science Bridges Project by Dr C.X. Wang
17:20-17:40	Discussions
17:40-18:20	Lab tour
18:30-20:00	Dinner

1. Minutes

1.1 Welcome Reception and Self-introduction

The UK delegation received a warm welcome. Prof. Hailin Zhang gave an introduction to the XDU colleagues present at the meeting. Dr Chengxiang Wang gave an introduction to the UK delegation. Then each UK delegate gave an introduction to him/herself and the institution he/she represents.

1.2. Welcome Speech and Introduction of XDU by Prof. Xinbo Gao (Head of Dept. of International Relations)

There are over 40,000 students in XDU, including 1400 PhD and 7000 master students, 1700 academics, including 900 Professors and Associate Professors. There are 3 state key laboratories and 4 key laboratories of the Ministry of Education. There are 17 academics at the State Key Lab of ISN in the domain of ICT. ISN is one of the best-known and the leading research groups in wireless networks in China.

In the 2006 Ranklist of Chinese University Engineering Programs, the Telecommunications Engineering Program in XDU was ranked No.1, the Network Engineering Program was ranked No.2 and the Electronic Information Warfare Technology Program was ranked No.1. In a more recent ranking, XDU was ranked as no. 2 in Telecommunications Engineering Program only after Tsinghua University.

UK delegates asked a few questions after Prof. Gao's presentation.

LH: Asked a question about the postdoctoral program.
JDL: In China, it is special program after the PhD. There are some difference between the Research Fellow posts in the UK and the postdocs in China.

IA: What does the "advisor" to PhD student mean?
JDL: In China, not every professor can supervise PhD students, only those who are qualified (the so-called PhD advisors) can supervise PhD students.

HH: What is required to retain the status of State Key Laboratory?
IA: What are the criteria to retain the status?
JDL: It is checked every five years. The labs of high quality that are measured by the number of publications (e.g., SCI indexed publications), the number of PhD students, funding and peer esteem. SY: History is also important.

1.3. Introduction of the School of Telecommunications Engineering, by Prof. Hailin Zhang (the Dean of the School of Telecommunication Engineering)

The School of Telecommunication Engineering has three departments: Communications Engineering, Information Engineering, and Electronic Technology. There are three Key Labs in the School, including State Key Lab of ISN, the Ministry of Education Key Lab of Computer Networks and Information Security, and the Ministry of Information Industry Key Lab of Wireless Communication.

The school is ranked as No. 1 in Xidian U. There are some 240 faculty members including 40 professors, and 70 associate professors; among them, they are 24 PhD advisors. There are some 240 PhD students and over 1200 graduate students. From 2004-2008, the School received funding of RMB214 Million (1GBP = 11.5 RMB). IA questioned how many researchers can be supported by 1 million RMB? JDL replied that unlike in Europe, the funding is not for hiring staff. It is mainly used for equipment, travel, publication and infrastructure.

1.4. Introduction of the State Key Lab of ISN, by Prof. Jiandong Li (head of the state key lab of ISN)

The members of the lab are drawn from the School of Telecom Eng. The establishment of State Key Lab of ISN was approved in 1989; The construction of buildings started in 1991. In 1995 the lab passed verification to be the state key lab. The lab is evaluated by expert groups every 5 years to decide whether it can keep its

statues as the state key lab. The research projects of ISN cover: software radio, cognitive radio, ad hoc networks, mesh networks, deep space communications, satellite communications, network coding (Prof. Ning Cai, one of the inventors of network coding, works at the ISN Lab), MIMO-OFDM system, adaptive antenna and interference cancellation, wireless network security, etc.

CXW: Is XDU involved in a 973 Cognitive Radio project as this project was mentioned in visits to other Chinese partners? How many partners are involved in this project?

JDL: Yes, XDU is involved in the project. There are about 10 project partners, mainly universities. The project is co-ordinated by BUPT (Beijing U. of Posts and Telecommunications). XDU is also involved in another 973 project on LTE, Prof. Jianhua Ge is heading the research activities of key techniques for LTE.

1.5. Introduction of the Mobile VCE by Simon Fletcher (on behalf of Dr Walter Tuttlebee)

1.6. Tea break and take group photo

It was really impressive that the photos were processed immediately and were given to the UK delegates in the next day morning.

1.7. Introduction of the UK-China Science Bridge Project by Dr C.X. Wang

1.8. Discussions

JDL: It is a difficult task for the delivery of (B)4G prototype as mentioned in CXW's presentation.

CXW: The prototype does not necessarily mean a complete 4G system. We only aim to deliver some components of a (B)4G system. The UC4G project does not have funding for either fundamental research or the development of (B)4G systems. The research results of some national key projects on some parts of (B)4G systems (such as LTE-A and IMT-A) can be used.

JDL: It is a hard job to integrate these results.

LH: It is impossible that we can develop a full-fledged (B)4G system. The work at WiCo (Shanghai) can be used for the (B)4G prototype. The simulation platform can be used by the UK partners, e.g., through operations using a web brower. Normally, there are some problems with collaborative research, e.g., in some EU projects, partners tend to develop their own work on the same topic, e.g., on channel models, each one developed its own channel models. (JZ: there are probably two problems with this, first, the work is repeated which results in waste of time and resources; second, if different simulation modules and channel models are used, it makes more difficult to compare the results based on these models.)

JDL: We can follow the recommendation by ITU. For example, we can use the channel models recommended by ITU.

CXW: The project has £100K to spend on prototype. Cognitive radio (CR) is a feasible idea. We can develop the software part using Matlab and equip the prototype with some CR hardware.

JZ: Such a system is already commercially available. What is our contribution?

LH: The CR prototype can be used by industrial partners on CR research.

HLZ: Could Chinese project partners jointly use the CR testbed?

CXW: The testbed can be jointly used via Internet.

HH: Southeast University (SEU) does some similar work on CoMP without multiple user MIMO, is the work at XDU and SEU on CoMP co-ordinated?

JDL: No. The work on CoMP at XDU and SEU are done independently.

HH: But they were all funded by the 863 program.

HLZ: In 863 program, there are also competitions.

LH: There are two competing telecommunications departments at Budapest University of Technologies and Economics.

JDL: Yes, different teams have different channels to obtain funding, e.g., 863, 973, MOST etc.

LH: Can you (Prof. Jiandong Li) elaborate on whether the (B)4G system will be based on OFDM or some alternative technologies, e.g., MC-CDMA, or LAS-CDMA developed by Prof. Daoben Li etc at BUPT? OFDM has its own problems.

HLZ: It seems that the 4G system will be based on OFDM to support data rate of 300Mbps. However, OFDM has some disadvantages as well, e.g., the power efficiency is low and PAPR is high. This is why SC-FDMA is used in the LTE uplink.

LH: The modern communications systems use some complicated technologies. We should consider alternatives, e.g., instead of using AMC, we can use constant modulation to reduce PAPR. We all know linear amplifiers have low power efficiency. For example, with Doherty modulation and amplifier, super fast data rate can be achieved using constant modulation with high power efficiency. Another example is CPM (Continuous Phase Modulation), which has both high spectral and power efficiency due to the phase continuity the constant-envelope waveform. GMSK (Gaussian Minimum Shift Keying) is also a continuous-phase frequency-shift keying modulation scheme. It has the advantage of reducing sideband power, which in turn reduces out-of-band interference between signal carriers in adjacent frequency channels. …

HH: In addition to the disadvantages due to sophisticated modulation and coding, we also need to be aware of the multiple access interference introduced by these systems (OFDM based?). One of the main goals in a wireless system is to control multiple access interference.

CXW: What is the perspective of CR used in (B)4G from the Chinese point of view (academia and industry)? And how to use it? For example, in Scotland, CR is regarded as a technology for long term. Is it feasible to use CR in 3-5 years or 5-10 years? Clearly, we think CR is a long-term research, not to be used in a short term.

JDL: We also think CR is a long-term research with many research topics, e.g., basic CR model, how to learn the radio environments, how to allocate different amount of resources to users. We believe CR will be used in (B)4G. In (B)4G, we will have different wireless technologies co-exist. The first stage of cognition can be simply to choose different wireless systems according to the radio environments and resources available.

JZ: We can regard heterogeneous networks as the first stage of CR. In this case, CR will definitely be used in (B)4G.

LH: What kind of simulation platforms do you use? (JZ: Does this mean we should base CR on one of these simulation platforms?)

JDL: NS-2, OPNET and OMNET are used.

1.9 Lab tour

Demo 1- Techniques for LTE at Prof. Jianhua Ge's lab: demo of one-hop relay on the uplink. The demo equipment does not have an RF part. Perfect channel and flat fading are assumed. High order QAM (64QAM) is used. The system can be configured through Matlab (e.g., channel and modulation and coding).

Demo 2 – Satellite communications. Prof. Kechu Yi demonstrated some research work on satellite communications, interference cancellation, etc. There are about 90 research students (PhD and Master) at Prof. Yi's group.

Demo 3 – Prof. Min Sheng demonstrated an ad hoc network based on WiMAX and WiFi.

2. Summary

2.1 (B)4G R&D Activities at XDU

XDU is a highly specialized university in electronic engineering. Its telecommunication school is one the major players in China in the R&D of wireless communications. The size, research scope, and research quality of the XDU research team are all very impressive. With a historical military background, XDU is taking up more and more R&D activities in civil telecom systems and has been able to transfer much of its long-accumulated expertise and know-how skills from military systems to civil systems.

2.2 Collaboration opportunities

XDU staffs have indicated the following (but not limited to) research interests for future collaboration:

- Ad-hoc networks for (B)4G (cooperative)
- SON for (B)4G
- Cognitive networks for (B)4G
- Cooperative PMP/Mesh Hybrid Networks for (B)4G
- Advanced MIMO Detector in the (B)4G Uplink

3. Contact

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A.8. Visit to Shangdong University (SDU)

By Prof. Alister Burr (University of York)

Time: 9:30-14:00, Monday 3 Aug 2009
Venue: School of Information Science and Engineering;
Wireless Mobile Communication and Transmission (WMCT) Lab
Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Prof. S. Yu (Bristol), Dr H. Hass (Edinburgh), Ms M. Steward (Turner), Dr X. Gu (BT), Dr T. H. Loh (NPL), Mr S. Bains (iXassociate).
- SDU: Prof Hongxiang Lou (Vice President), Prof. Dongfeng Yuan (Dean), Prof. Mingyan Jiang (Vice-Dean), Prof. Hongxiang Tou, Prof. Guanghua Tong, Prof. Jie Liu, Prof Zhiquan Bai, Prof. Haixia Zhang, Prof Yingji Zhong, Prof. Piming Ma, Dr Jian Sun, plus a number of PhD and Masters candidates from the Department.

Agenda:

9:30-9:45	Welcome reception and self-introduction
9:45-9:50	Introduction of SDU, by Prof. Hongxiang Lou
9:50-10:10	Introduction of School and the Wireless Mobile Communication and Transmission Lab, by Prof. Dongfeng Yuan
10:10-10:20	Introduction of the UK-China Science Bridge Project by Dr C.X. Wang
10:20-10:30	Introduction of the Mobile VCE by Prof L. Hanzo
10:30-10:40	SDU staffs and the UK delegation take photos
10:45-12:20	Lab tour, by Prof. Dongfeng Yuan
12:20-13:00	Further discussions
13:00-14:00	Dinner

1. Minutes

1.1 Welcome Reception

The UK delegation received a warm welcome. Prof. Yuan introduced his colleagues from Shandong University. The UK delegation members introduced themselves and their research groups and interests. Several of the UK delegation members mentioned links with Shandong University or province, notably Dr Cheng-Xiang Wang, who studied at the University for seven years, and whose Master's thesis was supervised by Prof. Yuan.

1.2. Introduction of SDU by Prof. Hongxiang Lou

Shandong University is one of the oldest in China, being founded in 1901. (It also likes to trace its roots back to Confucius, who came from Shandong Province). It is one of the biggest universities in China, with an enrolment of over 10 000 students per year, six campuses in Jinan alone, and covering many disciplines. It is also one of the strongest universities in China, having recognised strengths in several areas, including Microelectronics, Materials Science and Mathematics. It is an ambitious university, seeing international collaboration as a tool to make the University bigger and stronger. It also has associations with many large companies in Shandong Province. SDU is a big and ambitious university. It has 6 campus in Jinan and enrols about 10,000 new students (including undergraduates and postgraduates) each year.

1.3 Introduction of the School and the WMCT Lab, by Prof. Dongfeng Yuan

Prof. Yuan then gave an introduction to the School and to his laboratory. He welcomed the UK delegation and said how pleased he was to meet old friends and to make new ones, mentioning several members of the delegation. He showed a short film introducing the School of Information Science and Engineering. It was founded in 2001 by the merger of several Departments in the area of Electronic Engineering, and has 171 faculty and staff and an enrolment of more than 2000 students. The School encompasses Departments of Electronic, Communications and Optoelectronic engineering, and also runs a total of 8 doctoral programmes. It is the founder of the Shandong section of IEEE, and has sponsored international conferences, including IEEE conferences.

Prof. Yuan continued to introduce his lab: Wireless Mobile Communications and Transmission. The oldest research area is channel coding, extended subsequently to other physical layer areas, including Interleave Division Multiple Access (IDMA) and network coding. Since 2005 the research areas have been extended to higher layer and cross layer issues including radio resource management (RRM) and cognitive radio. Current research areas and projects include: cross layer techniques, relaying and cooperative communications, and multiple access for IMT-Advanced. Proposals for the ITU are under development, giving a joint view of time, space and frequency, and involving both IDMA and CDMA. A non real-time MIMO testbed exists and a real-time one is nearing completion. In the context of the Science Bridges project, areas of interest include the application of the MIMO testbeds, cross-layer design and RRM, and cognitive radio.

1.4. Introduction of the UK-China Science Bridge Project by Dr C.X. Wang

1.5. Introduction of the Mobile VCE by Prof L. Hanzo

1.6. Lab tour

Following a group photograph (the result of which was delivered to the delegation before leaving), the delegation toured some of the laboratories. This included a laboratory sponsored by Synopsis, including both COSSAP for communication system simulation, and ASIC design tools. The ASIC design activity is a relatively recent introduction.

The development of the MIMO real-time test-bed was also demonstrated. At present only SISO transmission is available, but MIMO is under development. SISO transmission of a real-time video stream was demonstrated. The testbed uses OFDM transmission, and hence is adaptable to IEEE 802.11n and 802.16 standards. Initially Alamouti space-time block codes will be used, but it can be adapted to other schemes.

A combined wireless video transmission system and wireless sensor network was also demonstrated, for video surveillance applications. The sensor network can be used for movement detection, for example, and then turn the video camera on. The focus of the research is mainly on routing and MAC layer functions.

1.6 Further discussions after the tour

The meeting then reconvened, and Shandong staff introduced themselves and their research interests:
Prof. Mingyan Jiang: signal processing and optimisation for communications, including cross layer design and particle swarm optimisation;
Prof Haixia Zhang: MU-MIMO, resource allocation, beamforming, precoding, STC, MIMO with partial CSI. Has worked with Prof Josef Nossek;
Dr Jian Sun: Synchronisation and channel estimation, iterative detection, reconfigurable devices;
Prof. Zhiquan Bai: UWB, especially impulse radio, cognitive radio (inc. cognitive UWB), M-ary modulation for UWB, cooperative systems;
Prof. Piming Ma: Coding, especially LDPC, including structured design of parity check matrices, application to OFDM;
Dr Zhu Xuemei: Cross-layer design, including physical and higher layers. Based on theoretical analysis, rather than simulation.

A discussion ensued on cross-layer methods, in the course of which two PhD candidates described their work:
Mr Zhangyu Guan: cross-layer methods for resource allocation using game theory – in particular "a judicious mixture of cooperation and competition";
Ms Li Ma: cross-layer design based on "effective capacity" (i.e. maximum rate supportable given certain QoS constraints on BER and delay, etc).

Methodology of cross-layer design is both top-down and bottom-up – it was noted that the more layers included, the more difficult, especially as different QoS measures are proper to different layers.

2. Summary

2.1 (B)4G R&D Activities at SDU

SDU has quickly emerged as an important player in China in the R&D of wireless communications. Its research activities span a wide scope from RRM to the physical layer design and to implementations. Over recent years, the research team in SDU have shown great interest in cross-layer design and has produced fruitful results. SDU has hosted the first international workshop in cross-layer design and is gradually building up its reputation in this research area.

2.2 Collaboration opportunities

SDU staffs have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- Application of MIMO testbed
- Cross-layer design and radio resource management
- Cognitive radio RRM

3. Contact

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A.9. Visit to Tsinghua University (THU)

By Dr Xuemin Hong (Heriot-Watt University)

Time: 16:30-18:00, Wednesday 5 Aug 2009

Venue: Network integration for ubiquitous Linkage and Broadband (NiuLab), Dept. of Electronic Engineering, Tsinghua University
Communication Systems and Networking Division, Tsinghua National Laboratory of Information Science and Technology

Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr W. Tuttlebee (M-VCE), Prof. J. Mcgeehan (Bristol), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Prof. S. Yu (Bristol), Dr H. Hass (Edinburgh), Ms M. Steward (Turner), Dr X. Gu (BT), Dr T. H. Loh (NPL), Mr S. Bains (iXassociate).
- THU: Prof. Zhisheng Niu, plus a number of postgraduate students.

Agenda:

17:00-18:00 Lab tour and discussions

1. Minutes

After a full day workshop at Tsinghua university, Prof. Zhisheng Niu led the UK delegation to briefly visit the Network Integration for Ubiquitous Linkage and Broadband (NiuLab) lab. The research interests of NiuLab include 1) Multi-AP dversity for interference avoidance; 2) Cooperative diversity in wireless multihop networks; 3) Triple-play network integration for always-best-connected; 4) Multi-dimensional radio resource management; and 5) Power-efficient new generation networks. A demonstration was shown for mobile multimedia broadcasting based on integrated communication and broadcast networks. The hardware testbed integrates a WiMax communication system and a digital video broadcasting system to provide interactive high definition multi-media services.

2. Summary

2.1 (B)4G R&D Activities at THU

THU consistently ranks first in Chinese universities and has a very high reputation in its engineering disciplines. THU is a major player in wireless communications and has led major national projects in mobile communications and digital video broadcasting systems. A National Laboratory of Information Science and Technology was recently established based on Tsinghua.

2.2 Collaboration opportunities

THU staffs have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- Diverse access network
- Converged core network
- Green radio network
- Cross-layer design (opportunistic networking)
- Spatial reuse in multi-hop wireless networks

3. Contact

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A.10. Visit to Beijing University of Post and Telecommunications (BUPT)

By Dr Xuemin Hong (Heriot-Watt University)

Time: 14:30-18:00, Thursday 6 Aug 2009
Venue: ROOM 502, Administration Building, BUPT
Wireless Technology Innovation (WTI) Institute, BUPT
Key Lab of Universal Wireless Communications (UWC), Ministry of Education (MoE)
Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Dr W. Tuttlebee (M-VCE), Dr X. Gu (BT), Dr T. H. Loh (NPL), Dr. K. Yang (Essex)
- BUPT: Prof. Xiaomin Ren (Vice President of BUPT), Ms. Chunxia Ren (Vice Director, International Office), Ms. Xinying Tang (International Office), Prof. Ping Zhang (Director of the WTI Institute, Director of the Key Lab of UWC), Associate Prof. Qimei Cui (Assistant Director of the Key Lab of UWC), Associate Prof. Guixia Kang, Dr Xiaodong Xu, Dr Qiang Wang, Dr Yuexia Zhang

Agenda:

14:30-14:50	Meeting with the Vice President of BUPT, Prof. Xiaomin Ren
14:50-15:20	Introduction of UWC, by Prof. Ping Zhang
15:20-15:50	Wireless Remote Healthcare Monitoring in City Communities on Key Personnels, by Dr Guixia Kang
15:50-16:20	FuTURE B3G/4G TDD MIMO OFDM System, by Dr. Qimei Cui
16:20-17:20	Lab tour, by Dr Qimei Cui, Dr Guixia Kang, and Dr Qiang Wang
17:20-18:00	Further discussions
18:00-20:00	Dinner

1. Minutes

1.1 Welcome Reception

The BUPT vice President Prof. Xiaomin Ren hosted a reception to welcome the UK delegation. Prof. Ren mentioned that BUPT has enjoyed a long-standing collaboration with the UK academics and emphasised the wish to further strengthen the collaboration through the UC4G Science Bridge project.

1.2. Presentation by Prof. Ping Zhang

1.2.1 "Introduction of UWC"

UWC is established as a key lab under the Ministry of Education, China. Based on different research focuses, UWC is structured into four research centres: mobile communications centre, wireless ubiquitous networks architecture centre, short range wireless communication centre, and ubiquitous wireless environment centre. Currently UWC has 39 research staffs including 2 academicians of Chinese Academic of Engineering (CAE), 19 professors, and 15 associate professors. UWC staffs have accomplished a number of national/enterprise projects and have established impressive profiles of patents and publications. The research funds on 2006 accumulated up to twenty millions RMB (about 2M pounds). UWC has world-wide outreach activities with R&D partners located in 20 countries. In addition, UWC is heavily involved in knowledge-transfer activities as well as the development and industrialization of practical wireless systems, including the well-known TD-SCDMA system.

1.2.2 Q&A:

1) Prof. Hanzo (Southampton) asked the BUPT's vision on (B)4G. Prof. Zhang (BUPT) commented that there are several problems in 3GPP LTE need to be solved in (B)4G:

- First, multiplexing/diversity MIMO faces deployment problems in practice since the antenna array requires large space. Beamforming could be more realistic and is particularly beneficial to enhance the cell edge performance.
- Second, the LTE adopts a flat architecture to reduce end-to-end delay but has resulted in over-complicated NodeBs. From a deployment point of view, the NodeB complexity needs to be reduced.
- Third, the cell edge coverage has become the bottleneck of 3G performance. A potential solution to the cell edge problem is group cells, or coordinated multi-point (CoMP). However, CoMP faces huge deployment difficulties in practice due to the rising concern about the electro-magnetic pollution and environment protection.

2) Prof. Hanzo (Southampton) questioned the pros and cons of TDD and FDD systems. Prof. Zhang (BUPT) answered that the TDD system can potentially achieve better performance at the cost of increased implementation complexity. Prof. Hanzo (Southampton) commented that interference management is critical to both types of systems.

3) Dr. Tuttlebee (M-VCE) asked the time-scale of 3G deployment activities in China. Prof. Zhang (BUPT) explained that three 3G license was released in Jan 2009 and currently there are three 3G networks (CDMA2000, WCDMA, and TD-SCDMA) rolling out in China. Dr. Tuttlebee (M-VCE) commented that the 3G research dated back to as early as 20 years ago.

4) Dr. Wang (HWU) asked the time-scale of BUPT's researches on cognitive wireless networks and whether cognitive radio networks would be incorporated into (B)4G . Prof. Zhang (BUPT) clarified that there is no clear time-scale in BUPT and commented that cognitive radio may be first used in military applications.

1.3 Presentation by Associate Prof. Guixia Kang

1.3.1 "Wireless Remote Healthcare Monitoring in City Communities on Key Personnel"

Wireless e-health aims to develop wireless remote healthcare monitoring platforms for real-time health assessment of critical patients in city communities. The wireless e-health research in BUPT is sponsored by two main projects from the MOST. Prof. Kang indicated the wish to collaborate with UK universities on wireless e-health research in the UC4G Science Bridge project.

1.3.2 Q&A

1）Prof. Hanzo (Southampton) asked the availability of medical sensors. Prof. Kang replied that leading companies such as Philips and HP have developed a variety of small and convenient sensors.

1.4. Presentation by Associate Prof. Qimei Cui

1.4.1 "FuTURE B3G/4G TDD MIMO OFDM System"

Future Technologies for Universal Radio Environment (FuTURE) is a part of China High-Tech 863 program. The project involves 6 universities and 6 companies, with an ambitious goal to demonstrate pre-commercial B3G/(B)4G mobile networks by the end of 2010. BUPT is a key player in the FuTURE project and has successfully demonstrated Gbps wireless communication services over a 100MHz bandwidth in urban outdoor mobile scenarios.

1.4.2 Q&A

1）Prof. Hanzo (Southampton) asked the man power allocated to the FuTURE project in BUPT. Prof. Kang clarified that more than 200 students (about 50 PhD students and 150 MSc students) have worked on the FuTURE project from 2001 to 2009.

1.5 Lab tour

The B3G/(B)4G Gbps wireless communication platform and an E-health wireless remote monitoring platform were demonstrated during the lab tour. Dr. Xuemin Hong (HWU) was interested in the hardware architecture and baseband implementation methods of the Gbps testbed. Dr. Qiang Wang (BUPT) replied that the signals are sampled at the baseband at 122MHz and the entire baseband algorithms are programmed using VHDL. Various other questions were raised by the UK delegation members and answered by the BUPT staff.

1.6 Further discussions after the tour

Prof. Burr (York) asked the modulation type of the Gbps platform. Prof. Cui (BUPT) replied that adaptive modulation (up to 16-QAM) was deployed. Prof. Burr (York) further commented that multiplexing MIMO is required to achieve the reported 10bit/s/Hz spectrum efficiency. This is confirmed by Prof. Cui (BUPT).

2. Summary

2.1 (B)4G R&D Activities at BUPT

UWC at BUPT is among the best university-based labs in the field of wireless communications in China. The UWC's research activities encompass many aspects of (B)4G radio access networks ranging from the PHY layer to the network layer, and from theoretical research to practical implementations. The size of UWC's research team and the coherence of its research activities are rarely matched by the UK universities. In particular, UWC's strong commitment of converting theories to practical systems is very impressive.

2.2 Collaboration opportunities

BUPT staff have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- CoMP transmission network
- Wireless relay networks
- Wireless networks for special environments (e.g., emergency response, damaged networks)
- Wireless e-health

3. Contact

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A.11. Visit to China Mobile (CM)

By Melanie Stewart (Turner Broadcasting)

Time: 09:00-14:00, Friday 7 Aug 2009
Venue: China Mobile Research Institute, Beijing
Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. A. Burr (York), Prof. Z. Sun (Surrey), Dr R Atkison (Strathclyde), Dr W. Tuttlebee (M-VCE), Dr X. Gu (BT), Dr T. H. Loh (NPL), Dr. K. Yang (Essex), Mr S. Bains (ix Associates), Ms M. Stewart (Turner Broadcasting).
- China Mobile Research Institute: Mr Bill Huang (General Manager), Ms Yuhong Huang (Director, Dept. of Wireless Communication), Dr Chunfeng Cui (Project Manager), Mr Qixing Wang, Mr Weihui Dong, Mr Lei Lei, Ms Xing Chen, Mr Sen Bian, Mr Bo Zhou.
- CATR: Ms Wei Li.

Agenda:

09:10-09:15	Welcome from China Mobile Research Institute
09:15-09:30	Self introduction of delegates
09:30-10:00	Introduction to the UK-China Science Bridge project by Dr Cheng-Xiang Wang
10:10-11:20	Introduction to the Mobile VCE & research programmes by Dr Walter Tuttlebee
11:00-12:00	Introduction to the China Mobile Research Institute by Yuhong Huang
12:00-12:45	Lab tour & future product demonstrations
13:00-14:00	Lunch

1. Minutes

1.1 Welcome from China Mobile Research Institute

Dr Chunfeng Cui from the Department of Wireless Communications, China Mobile welcomed the UK delegation.

1.2. Presentation by Dr Cheng-Xiang Wang

1.2.1 Dr Wang (HWU) provided an overview of the UK China Science Bridge project, including expected outcomes, an explanation of work packages 1 through 6 and governance structure to ensure success.

1.2.2 Q&A:

1) C. Chunfeng (CM) asked how China Mobile can get involved in the project, Dr Wang (HWU) replied that China Mobile are invited to participate in all work packages and industrial steering groups to provide influence to the project from the outset. China Mobile is also able to participate in future international workshops, although Dr Wang mentioned that the prototype stage is still unclear.

2) H.Yuhong (CM) asked what is the time schedule for the project. Dr Wang (HWU) replied that this information would be provided later in the presentation and that China Mobile has provided input onto the collaboration agreement.

1.3. Presentation by Dr Walter Tuttlebee

1.3.1 "Introduction to the Mobile VCE and current Core 5 Green Radio Work Package"

Dr Tuttlebee (MVCE) provided an overview of the Mobile VCE organisation, set-up and objectives. He also gave an overview of the current and Core 5 Green Radio Work Package.

1.3.2 Q&A:

There were a variety of questions asked by both the UK delegation and China Mobile team that were answered by Dr Tuttlebee.

1) What is the IPR policy of UK Science Bridge project? Dr Tuttlebee replied that it is not the same IPR policy as the MVCE. The foreground of knowledge can be accessed royalty free, further information will be shared based on the communicated IPR agreement of the project.

2) How much money is the UK Government contributing to the project? Dr Tuttlebee responded that the funding is matched.

3) Who retains ownership of the patents? The decision to patent is made by industrial members. If the decision to patent is made, then it is filed by the MCVE and any costs associated with this are also borne by MVCE. The originating University owns the patent with royalty free access to all industrial members. Non-members can license via either the MVCE or University.

4) Does industry have 50% ownership of the IPR? Non-exclusive access by member companies.

5) How do others use/access Mobile VCE IPR? Access is through the MVCE or University with a revenue split. Revenue from the MVCE component is used to sponsor further research work.

6) Where is research undertaken? Research is undertaken at the Universities. The Industrial members select the universities chosen to conduct the research.

7) Power consumption: Is the access only about radio or on cooling techniques as well? The Green Radio programme is focused on radio issues beyond LTE. Cooling is being looked at as a short-term energy reduction solution.

1.4 Presentation by Yuhong Huang, Director of Wireless Communication China Mobile

1.4.1 "Introduction on China Mobile"

The wireless communication research department was established in April 2000 and now has offices in Pakistan, USA and UK in addition to China. It mission is to be China Mobile's engine of Technology Innovation and it is responsible for the R&D Innovation Strategy. One of their biggest successes to date was the preparation for the Beijing Olympics in 2008 with the highest base station deployed being at 6,500m. Another area of focus is for social responsibility. It is a world class research centre and their areas of innovation include:

- Technical research, supporting existing infrastructure and testing of infrastructure that is ready for deployment
- Developing new services for China Mobile for example development of the exclusive OS system based on Android
- Collaboration with industrial partners and standards bodies
- Innovation strategy
- National strategy i.e. emergency communications etc

1.4.2 Q&A

1) CX Wang asked how much development of the OS was completed by CM. H. Yuhong answered that a portion of the development was performed by CM the by industrial partners.
2) Dr. Tuttlebee asked whether the patent portfolio is based on domestic or international patents. H. Yuhong replied that they are international patents for e.g., PCT.

1.4.3 "Introduction to TD-SCDMA"

The TD-SCDMA licenses was awarded on the 7th Jan 2009. There are three phases of TD-SCDMA system deployment. The first & second phases have been completed and the third is in progress. There are currently 157m SCDMA subscribers. Upon completion of phase three, 238 cities in China will have coverage. Phase three is due for completion in October 2009.

TD LTE Standardisation began in 2004, aiming for a downlink speed of 100Mbps, a uplink speed of 50 Mbps, and a delay of less than 10 ms. CM anticipates convergence of all wireless technologies to LTE / LTE+ in the future. TD LTE is flexible and provides capacity and coverage through spectrum utilisation and spectrum efficiency improvements. CM believes that TD LTE converged with FDD will provided economy of scale and support global roaming. International organisations and standards bodies are pushing LTE TDD/FDD. CM is also working with Vodaofone & Verizon Wireless on TD LTE and FDD LTE. TD SCDMA to evolve to TD LTE as mandated by the Chinese Government. Trials for TD-LTE are scheduled for 2010, with first phase of testing completed in June 2009. LTE FDD/TDD equipments are expected to be ready between Q4 2009 – Q2 2010 on the network infrastructure side, and between Q2 2010 – Q4 2010 for data cards and chipsets. Large scale trial for the TD-LTE network is scheduled for 2010, including POC, technical testing, and field trial of 3 cities, 100 cells sites. CM plans to showcase TD LTE at the Shanghai World Expo in 2010.

H. Yuhong stated that the technical evidence of both FDD and TDD indicates that TDD requires more effort to limit interference at base stations/mobiles. When pushed to capacity, FDD is ok.

1.4.4 Q&A

1) Dr Tong asked the question of how many elements were in the antenna, to which H.Yuhong answered that there were four elements.

2) Prof Hanzo expressed an interest in a potential collaboration with China Mobile in the utilisation of TD CTE for greater capacity.

3) Dr Wang asked if CM believed in the possibility of a 3G standards merging into a global standard. H Yuhong answered that their hope was for one global standard using TDD characteristics to improve performance.

4) Prof Hanzo asked about the data rate of the trailed systems. H Yuhong answered that it is average throughput rather than peak rate.

5) Dr Wang asked about the future project of CM with Southeast and BUPT universities. What is the reason for the focus on TDD? Is that based on students? H Yuhong responded that TDD was already under investigation last year. BUPT has a strong telecommunications history; other Chinese Universities are also fast growing.

1.5. Lab Tour & future product demonstrations

1.5.1 Lab tour and antenna demonstration

The UK delegation were kindly given a guided tour of the CM's next generation wireless facility – including a number of actual TD LTE base stations from a number of vendors including Alcatel, Datang etc.

The delegation was then given an overview of the TD SCDMA Antenna Improvement project. The project aims to reduce the size of the antennas in response to residents who have expressed concerns about radiation. The plan is to separate the connectors in order to reduce size; in essence it will be the same antenna at a reduced size.

Lastly the delegation was shown a number of products that China Mobile plan to release in the near future. Firstly a Mobile Payment solution using the SIM card, then their Mobile Widget & Mobile Market offering which is China Mobile's application store and lastly, OPhone which is an Operating System, based on Linux, that has been exclusively developed for China Mobile.

1.5.2 Q&A

1) Prof Hanzo asked how many timeslots and users could be supported? CM replied that this is dependant on usage.

2) Prof Hanzo asked what was the total capacity o of each base station? CM replied 10 MHz bandwidth and 20 Mbps.

3) Dr Wang mentioned that South East University had demonstrated 1Gbps to the UK delegation during their visit. CM replied that theirs is not a commercial offering, whereas the CM's implementation is.

4) Dr Tuttlebee asked which manufacturers has CM been evaluating? CM responded that Nokia Siemens Networks, Huawei, Ericsson. Alcatel, Datang, ZTE, Motorola are all being investigated.

5) Dr Tong asked whether the development of the new antenna system was all within CM. CM responded that the project has been undertaken with the help of an external company.

2. Contacts

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A.12. Visit to Chinese Academy of Telecommunication Research (CATR)

By Prof. Zhili Sun (University of Surrey)

Time: 14:30-17:30, Friday 7th Aug 2009
Venue: CATR of MIIT, CTTL, 11 Yue Tan Nan Jie, Beijing, 100045
Attendees:

- UK delegation: Dr C-X. Wang (HWU), Dr X. Hong (HWU), Prof. L. Hanzo (Southampton), Prof. J. Zhang (Bedfordshire), Dr K. Tong (UCL), Dr X. Chu (KCL), Prof. Z. Sun (Surrey), Dr W. Tuttlebee (M-VCE), Dr T. H. Loh (NPL), Dr. K. Yang (Essex)
- CATR-CTTL: Prof. Guili He (Director), Prof. Denian Shi (Chief Engineer), Prof. Xiang Zhang, Ms Wei Li, Mr Bo Li, Mr Peng He, Mr Dongyi Zou, Mr Xiang Wu, Mr Zhiiyong Liu, and Mr Peng Yang.

Agenda:

14:30-14:50	Self introduction
14:50-15:20	Introduction to CATR-CTTL, by Prof. Guili He (CTTL director)
15:20-15:50	Introduction to the UK-Science Bridge project by Dr C-X. Wang (HWU)
15:50-17:20	Lab tour, by Prof Denian Shi
17:20-18:00	Further discussions
18:00-20:00	Dinner

1. Minutes

1.1 Welcome Reception

The UK delegation was welcomed by the CATR-CTTL staff led by Prof. Guili He (director) and Prof. Denian Shi (chief engineer).

1.2. Presentation by Prof. Guili He

1.2.1 "Introduction to the CATR-CTTL"

China Telecommunication Technology Labs (CTTL), founded in 1981, was named under the authorization of the Ministry of Information Industry (MII) and the State General Administration for Quality Supervision, Inspection, and Quarantine (AQSIQ). Current CTTL is administrated by the China Academy of Telecommunication Research of MII (CATR) and was formed through service re-organization and resource concentration by merging three parts of CATR, i.e. the Research Institute of telecommunication Transmission (RITT), the telecommunication Metrology Centre (TMC) and the Research Institute for Industry Standard of Posts and Telecommunications (PTISR) into an unique body.

It is a leading high-tech laboratory on the combined missions of telecommunication technology development, telecommunication product standard and test methods research, telecommunication metrology standard and methods research, products inspection, verification and technical assessment as well as testing instrument metrology and evaluation of communication software.

The development strategy of CTTL is based on the research of telecommunication engineering technology with related fundamental theory and guided by the national and international telecommunication markets to provide comprehensive services and support to the governmental departments, network operators and manufacturers. The labs has established its quality system according to the ISO/IEC 17025 and achieved successfully accreditation certificates both from the China national accreditation board for laboratories (CNAL) and foreign accreditation bodies (e.g. Datech , Germany). The Accredited scope of the laboratories covers various telecommunication products including all kinds of telecommunication terminals, accessing equipment, transmission equipment, exchange, IP network equipment, multi-media communication equipment, cable, power supply equipment as well as their reliability, electrical safety and electromagnetic compatibility (EMC).

CTTL has become an advanced national base in large scale with integrate function for telecommunication and information equipment testing and inspection as well as metrology and calibration of measuring instrument ,providing open services to manufacturers and other clients both nationwide and worldwide . CTTL is a designating test laboratory for implementation of APEC-TEL-MRA and also the location of the Secretariat for APEC TEL MRA Working Group in China.

CTTL had been granted following 12 authorizations by the governmental administrations till 2004:

- National Telecommunication Metrology Station----Authorized by AQSIQ
- National Telephone Quality Supervision and Testing Centre----Authorized by AQSIQ
- National Scientific and Technical Results Testing Appraisal Body for Telephone products ---Authorized by AQSIQ and the Ministry of Science and Technology
- China Testing Body for Network Access of Telecommunication Equipment---Authorized by MII
- National Laboratory for China Compulsory Certification (CCC)---Authorized by National
- Telecommunication Metrology Centre---Authorized by MII
- Graphic and Text Communication Equipment Quality supervision and Testing Centre, MII---Authorized by MII
- Mobile Communication Equipment Quality Supervision and Testing Centre (Beijing), MII---Authorized by MII
- Telephone Switching Equipment Quality Supervision and Testing Centre (Beijing), MII---Authorized by MII
- Post and Telecommunication Industry Products Quality Supervision and Testing Centre, MII---Authorized by MII
- National Telecommunication Metrology Station----Authorized by AQSIQ
- EMC Test Centre for Telecommunication Equipment , MII---Authorized by MII

1.3 Discussion and topic for collaborations:

- Green radio
- Energy consumption of the telecom equipment and terminals
- Telecom device and service for environmental protections

1.4 Lab tour

The UK delegation visited the following departments and test equipment:

- Radio communications （including TD-SCDMA and WAPI tests）
- Fixed network communications
- Communication terminals
- Telecom metrology
- EMC test
- Safety test
- Environmental & reliability test
- Environmental protection test

2. Summary

2.1 (B)4G R&D Activities at CATR-CTTL

CATR-CTTL will be able to carry out research to evaluate (B)4G terminals and network equipment including their energy consumption and to standardise (B)4G equipment. CATR-CTTL will also be involved in R&D for (B)4G-related testing systems. CATR-CTTL will launch into green radio research.

2.2 Collaboration opportunities

CATR-CTTL staff have indicated the following (but not limited to) research interests for future collaboration with the UK partners:

- Green radio
- Energy consumption of the telecom equipment and terminals: Testing and Standardization
- R&D for (B)4G testing systems

3. Contact

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Appendix B: Some Local News Reports

B.1 News from the University of Bristol

http://www.bristol.ac.uk/ccr/news/2009/38.html

UK delegation visits research collaborators in China

10 August 2009

Professor Joe McGeehan (Director) and Professor Siyuan Yu of the Centre for Communications Research at the University of Bristol recently participated in a two-week visit (26th July - 7th August 2009) by the UK members of a consortium, established under the Science Bridges programme, to academic and industrial organisations in China.

The visit was funded as part of a grant awarded by the Research Councils UK to a consortium of UK and Chinese universities. This aims to accelerate the deployment of research knowledge, deepen and strengthen current research links, enable the acquisition of new skills and encourage wealth creation through improving the transfer of research and expertise from the research base to businesses and other users by building science and innovation bridges with world-class universities and high-tech businesses. The consortium members hope to establish a long-term sustainable collaboration between the UK and China in the area of next generation (4G) mobile communication systems by supporting collaborative research, mutual visits, exchange of researchers, and rapid technology transfer and commercialisation.
It is essential in the development of the next global standard for mobile communications, that key researchers in both China and the UK work closely together in fundamental R&D.

Professor Joe McGeehan, Director Centre for Communications Research

A series of workshops, visits and meetings were held to discuss the latest research being conducted on 4G mobile communication systems in the UK and China, and discussions were held on methods of collaborating. Whilst in China, visits made included those to:

- Shanghai Research Center for Wireless Communications (WiCo)
- Jushri Wireless Technologies Inc.
- Huawei Technologies Co. Ltd.
- Shanghai Jiaotong University (SJTU)
- Southeast University (SEU)
- Huazhong University of Science & Technology (HUST)
- Xidian University (XDU)
- Shandong University (SDU)
- Tsinghua University
- Beijing University of Posts and Telecommunications (BUPT)
- China Mobile Communications Co.
- China Academy of Telecommunication Research (CATR)

Full details of the grant were published in a previous news article.

B.2 News from WiCO

http://www.shrcwc.org/html/hezuojiaoliu/hezuodongtai/2009/0820/268.html

中英科学桥"4G 无线移动通信研发"项目英国专家代表团访问中心

2009-08-20 10:05 **来源**:**科研**开发部作者:陈阳点击: 235 **次**

2009 年 7 月 27 日上午，中英科学桥"4G 无线移动通信研发"项目英国专家代表团一行近 20 人访问中心。代表团专家分别来自 Mobile VCE, Heriot-Watt University (HWU), University of Bristol, University of Bedfordshire, University of Edinburgh, King's College London, University of Southampton, University of Strathclyde, University College London (UCL), University of Surrey, University of York, National Physical Laboratory, Turner Broadcasting System Europe Limited, Telecom MODUS Ltd. British Telecom …。上海无线通信研究中心作为中英科学桥"4G 无线移动通信研发"项目中方牵头单位，也是该项目被英国政府正式立项后，英国代表团访问中国的首站。

上海无线通信研究中心副总工杨旸博士、科研开发部部长熊勇博士等出席了接待。熊勇博士代表中心欢迎代表团来访并对中英合作模式表示高度肯定和信心；陈阳女士简要介绍了中心的国际合作概况及中英 4G 合作发展设想；杨旸博士重点介绍了中心测试验证平台研发的进展和构想；徐景博士和胡宏林博士分别介绍了研发一部和研发二部的研发重点。

中英双方就合作项目具体实施进度计划、预期成果交付进度和未来成立中英 4G 联合研究中心的设想进行了充分的交流讨论。会后，代表团专家参观了中心的测试演示大厅和国际联合研究实验室。

B.3 News from HUST

http://ei.hust.edu.cn/details.aspx?ID=2469

7 月 30 日英国代表团 20 人将来我系交流访问

2009 年 7 月 19 日

我系参与的中英政府间重大合作研究项目——中英科技桥项目：R&D on 4G Wireless Mobile Communications 获得英国政府正式批准，获得 EPSRC 的科研合作交流经费 9 3 万英镑用于资助双方交流合作。作为这个项目的重要组成部分，英方参与单位（共计 10 所大学和三家工业合作伙伴）组成联合访问代表团（约 20 人）**将于 2009 年 7 月 30 日访问我系，并于下午 15：30 在系会议室和我系师生座谈，探讨可能的合作方向和内容。欢迎我系教职员工参与座谈会**，与英国代表团交流与合作。

时间：7 月 30 日下午 3：30

地点：电信系互联网中心会议室（东校区）

题目：UK-China Science Bridges: R&D on 4G Wireless Mobile Communications

报告人：**王承祥博士**

B.4 News from SDU

http://www.view.sdu.edu.cn/news/news/sdyw/2009-08-04/1249346241.html

中英科技桥项目英方科学家代表团访问山大

2009-08-04 08:37　　点击人次：

［本站讯］8 月 3 日，中英科技桥项目——“R&D on 4G Wireless Mobile Communications”英方科学家代表团一行十余人到山东大学交流访问。双方就项目合作的相关事宜进行了座谈。山东大学副校长娄红祥出席座谈会并讲话。会后，英方代表团重点参观了由山东大学自行研制的“开放式 MIMO 试验平台”，并就如何深入地开展合作进行了热烈友好的讨论。

座谈会上，娄红祥代表学校对英国科学家的到访表示热烈欢迎，他介绍了山东大学的悠久历史及基本情况，并表示希望通过本次合作交流进一步加强与英国相关学校的科技交流合作。信息学院院长袁东风介绍了信息学院的基本情况，详细介绍了该项目山东大学主要合作承接方及宽带无线移动通信与传输实验室的研究方向、已完成及在研的主要项目。英方项目负责人王承祥博士介绍了中英科技桥项目的背景和意义，重点介绍了子项目“R&D on 4G Wireless Mobile Communications”实现目标、实施阶段及各阶段的具体工作形式。英方代表团成员、南安普敦大学 Prof. Lajos Hanzo 介绍了 Mobile VCE（英国移动通信虚拟研究中心）的一些基本情况。国际合作与交流处处长佟光武以及科技处、信息学院相关人员作为中方代表参加会议。

据悉，英国政府于 2006 年启动首轮科技桥项目，以支持英国和美国已有的合作朝着商业化和产业化目标发展，第二轮科技桥拓展到中国和印度。这些资助为英国研究机构与合作国的世界一流高校和高技术企业提供交流，加快推进部署研究所得知识，加深并加强已有研究合作关系，并通过提高科研成果从研究机构向企业的转移来获取新技能并鼓励创造财富。2008 年，英国研究理事会资助 1200 万英镑用于英国与中国、印度、美国的大学及科研机构间的科技桥项目，其中，中英科技桥有 4 个项目获得资助，英美和英印各有 3 个项目获得资助。“R&D on 4G Wireless Mobile Communications”项目作为 4 个获得资助的项目之一，由山东大学校友、英国赫瑞•瓦特大学王承祥博士主持，将与山东大学、清华大学、东南大学、华中科技大学、上海交通大学等高等院校及中国移动、华为公司、中兴公司、中国电信研究院等工业界成员合作。项目重点关注 4G 移动通信系统关键技术的研究与开发，旨在加强与中国 4G R&D 高等学校及电信公司的联系，形成 Mobile VCE 内的中英合作组以最终建成 4G 无线移动通信系统的中英联合研究开发中心。

B.5 News from BUPT

http://www.bupt.edu.cn/news/view.asp?id=3385

8 月 6 日，中英科技桥项目——4G 移动通信的研发（UK-China Science Bridges-- R&D on 4G Wireless Mobile Communications）英方代表团一行近 20 人访问了我校，任晓敏副校长接见了客人。

任副校长对来访的各位学者和专家表示了热烈欢迎，并向客人介绍了我校的基本情况，特别是我校在通信和信息技术领域的特色以及优势。他表示很高兴我校做为研究成员之一参与中英科研与学术合作，希望北邮今后与英国的各知名院校及机构建立起更广泛的沟通与合作。会见后，代表团访问了我校 WTI 无线新技术研究所，双方就相关领域的科研合作进行了沟通与交流。英方代表团成员有来自赫瑞瓦特大学、爱丁堡大学、南安普顿大学、英国移动通信虚拟研究中心（Mobile VCE）、英国电信、国家物理实验室等著名大学和机构的多位学者专家。我校出席会见的有张平教授、崔琪梅副教授、国际处任春霞副处长等。

英国政府于 2006 年启动首轮科技桥项目，以支持英国和美国已有的合作朝着商业化和产业化目标发展，第二轮科技桥已拓展到中国和印度。这些资助为英国研究机构与合作国的世界一流高校和高技术企业提供交流，加快推进部署研究所得知识，加深并加强已有研究合作关系，并通过提高科研成果从研究机构向企业的转移来获取新技能并鼓励创造财富。（见英国研究理事会 http://www.rcuk.cn）中英科技桥项目由英国研究理事会（RCUK）资助，2009 年中英科技桥资助项目为 4 个，其中之一为“4G 移动通信的研发”。北京邮电大学、华中科技大学、山东大学等 7 所大学以及上海无线通信研究中心、华为、中国移动研究院 3 个企业做为中方合作伙伴参与该项目的研发。(摄影：刘如林)