Feasibility Study on a UK-China Open Access (B)4G Wireless Mobile Communication Testbed

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(UC4G Beijing Workshop, 24 August 2010)

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Outline

I. Background and Motivation

- **UK-China Science Bridges: R&D on (B)4G Mobile Wireless Communications**
  - **Duration**: 3 years (01/08/2009-31/07/2012)
  - **Value**: £1,174,258 (fEC) or £939,623 (RC contribution)
  - Include 6 work packages
- **Work Package 4: Prototype Development**
  - **Objective:** To develop prototypes and test/verify findings using wireless testbeds and to facilitate proof of concept, technology transfer, and commercialisation.
  - **Deliverables:**
    - (B)4G wireless communication technology prototype;
    - IPR applications;
    - reports and posters regarding the verification results of developed (B)4G technologies using the wireless testbeds.
  - **Milestone:** Prototype development and verification of (B)4G wireless technologies.
  - **Duration:** 21 months (01/08/2010-30/04/2012)
  - **Funding:** ~ £100k

Motivation of Building (B)4G Testbeds

- **Drawbacks of software simulators**
  - **Simulators provide limited fidelity to real-world wireless systems**
    - Simplifying channel models
    - Unrealistic interfering conditions
    - Simplifying mobile user behaviours
  - **Simulations usually fall short of addressing important practical issues**
    - Implementation impairments (RF, baseband fixed point)
    - Real-time requirements
    - Hardware complexity
- **There is an increasing need for a (B)4G testbed to**
  - Test new concepts in reality (proof of concept)
  - Calibrate simulation results
  - Identify important problems and steer R&D efforts
  - Showcase advanced technologies
  - Facilitate knowledge transfer and technology commercialisation

(B)4G and Existing Wireless Testbeds

- **Roadmap to 4G: LTE, LTE-Advanced, and IMT-Advanced**

		Rel. 8 LTE	**LTE-Advanced**	**IMT-Advanced**
Peak data rate	DL	300 Mbps	1 Gbps	1 Gbps
	UL	75 Mbps	500 Mbps	
Peak spectrum efficiency	DL	15	30	15
	UL	3.75	15	6.75
RF Bandwidth		20 MHz	100 MHz	100 MHz

- **Some testbeds visible on the Internet and in the literature**
  - **Link level testbeds (single user, single link)**
    - Under various names: MIMO-OFDM, software defined radio (SDR), etc.
  - **System level testbeds (multi-cell, multi-link)**
    - EASY-C (Germany), FuTURE (China), KDDI (Japan)
  - **Commercial demos**
    - Ericsson, Nokia-Siemens, Huawei, etc...

Commercial Demos

- There are many commercial demos on LTE and "4G".
- Detailed technical information of these demos is not accessible to the public.

Technology Demos

[edit]

- In September 2006, Siemens Networks (today Nokia Siemens Networks) showed in collaboration with Nomor Research the first live emulation of a LTE network to the media and investors. As live applications two users streaming an HD-TV video in the downlink and playing an interactive game in the uplink have been demonstrated.[22]
- The first presentation of an LTE demonstrator with HDTV streaming (>30 Mbit/s), video supervision and Mobile IP-based handover between the LTE radio demonstrator and the commercially available HSDPA radio system was shown during the ITU trade fair in Hong Kong in December 2006 by Siemens Communication Department.
- In February 2007, Ericsson demonstrated for the first time in the world LTE with bit rates up to 144 Mbit/s[23]
- In September 2007, NTT docomo demonstrated LTE data rates of 200 Mbit/s with power consumption below 100 mW during the test.[24]
- In November 2007, Infineon presented the world's first RF transceiver named SMARTi LTE supporting LTE functionality in a single-chip RF silicon processed in CMOS [25][26]
- At the February 2008 Mobile World Congress:
  - Huawei demonstrated Long Term Evolution ("LTE") applications by means of multiplex HDTV services and mutual gaming that has transmission speeds of 100 Mbps.
  - Motorola demonstrated how LTE can accelerate the delivery of personal media experience with HD video demo streaming, HD video blogging, Online gaming and VoIP over LTE running a RAN standard compliant LTE network & LTE chipset.[27]
  - Ericsson EMP (now ST-Ericsson) demonstrated the world's first end-to-end LTE call on handheld[7] Ericsson demonstrated LTE FDD and TDD mode on the same base station platform.
  - Freescale Semiconductor demonstrated streaming HD video with peak data rates of 96 Mbit/s downlink and 86 Mbit/s uplink.[28]
  - NXP Semiconductors (now a part of ST-Ericsson) demonstrated a multi-mode LTE modem as the basis for a software-defined radio system for use in cellphones.[29]
  - picoChip and Mimoon demonstrated a base station reference design. This runs on a common hardware platform (multi-mode / software defined radio) with their WiMAX architecture.[30]
- In April 2008, Motorola demonstrated the first EV-DO to LTE hand-off - handing over a streaming video from LTE to a commercial EV-DO network and back to LTE.[31]
- In April 2008, LG Electronics and Nortel demonstrated LTE data rates of 50 Mbit/s while travelling at 110 km/h.[32]
- In April 2008 Ericsson unveiled its M700 mobile platform, the world's first commercially available LTE-capable platform, with peak data rates of up to 100 Mbit/s in the downlink and up to 50 Mbit/s in the uplink. The first products based on M700 will be data devices such as laptop modems, Expresscards and USB modems for notebooks, as well other small-form modems suitable for consumer electronic devices. Commercial release is set for 2009, with products based on the platform expected in 2010.
- In November 2008 Motorola demonstrated industry first over-the-air LTE session in 700 MHz spectrum[33].
- Researchers at Nokia Siemens Networks and Heinrich Hertz Institut have demonstrated LTE with 100 Mbit/s Uplink transfer speeds.[16]
- At the February 2009 Mobile World Congress:
  - Huawei demonstrated the world' s first unified frequency-division duplex and time-division duplex (FDD/TDD) long-term evolution (LTE) solution.
  - Aricent gave a demonstration of LTE eNodeB layer2 stacks.
  - Setcom Streaming a Video [34]
  - Infineon demonstrated a single-chip 65 nm CMOS RF transceiver providing 2G/3G/LTE functionality[35]
  - Launch of ng Connect program, a multi-industry consortium founded by Alcatel-Lucent to identify and develop wireless broadband applications.[36]
  - Motorola provided LTE drive tour on the streets of Barcelona to demonstrate LTE system performance in a real-life metropolitan RF environment [37]
- In May 2009 Setcom Streaming HD Video at GSMA MWC and LTE World Summit
- In July 2009 Nujira demonstrated efficiencies of more than 60% for an 880 MHz LTE Power Amplifier[38]
- In August 2009, Nortel and LG Electronics demonstrated the first successful handoff between CDMA and LTE networks in a standards-compliant manner [39]
- In August 2009, Alcatel-Lucent receives FCC certification for LTE base stations for the 700 MHz spectrum band.[40]
- In September 2009, Nokia Siemens Networks demonstrated world's first LTE call on standards-compliant commercial software.[41]
- In October 2009, Ericsson and Samsung demonstrated interoperability between the first ever commercial LTE device and the live network in Stockholm, Sweden.[42]
- In October 2009, Alcatel-Lucent's Bell Labs, Deutsche Telekom Laboratories, the Fraunhofer Heinrich-Hertz Institut and antenna supplier Kathrein conducted live field tests of a technology called Coordinated Multipoint Transmission (CoMP) aimed at increasing the data transmission speeds of Long Term Evolution (LTE) and 3G networks.[43]

http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution

Outline

I. Background and Motivation

II. Overview of Existing Link Level Testbeds

III. Overview of Existing System Level Testbeds

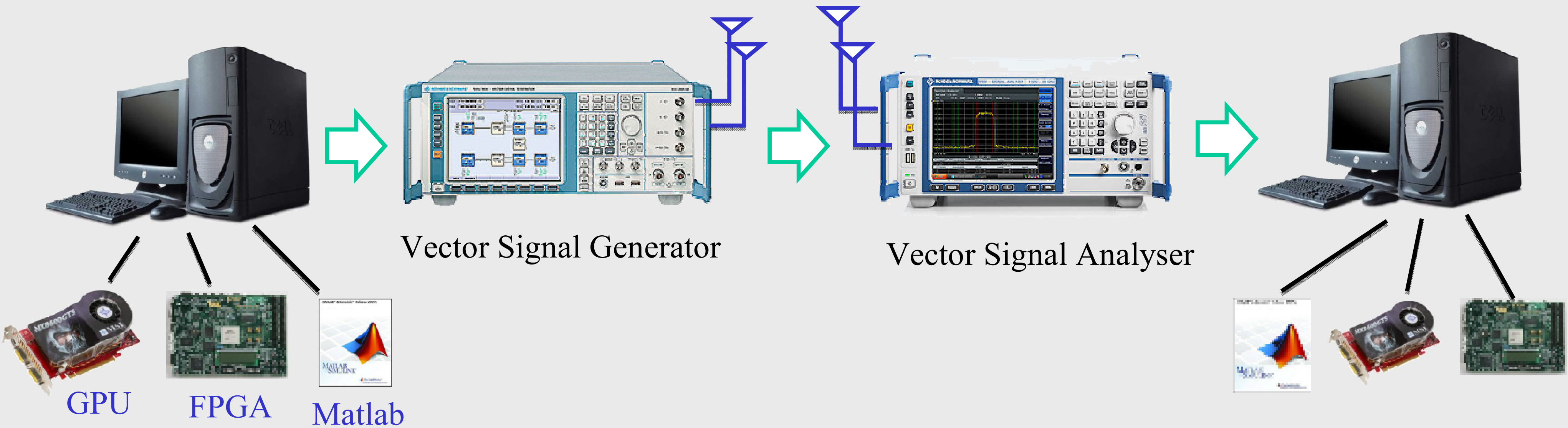
IV. Suggestions and Future Work

II. Overview of Existing Link Level Testbeds

- **There is a wealth of link level testbeds developed under different names**
  - MIMO testbed
  - MIMO-OFDM testbed
  - LTE testbed
  - WLAN testbed
  - Software defined radio (SDR) testbed
- **A survey of existing link level testbeds showed that**
  - Most carrier frequencies are located on 2.4/5.2 ISM bands
  - Most bandwidths are below 40 MHz, with only one exception (HHI: 100 MHz)
  - Most real-time testbeds involve FPGA, with only one exception (MS-Asia SORA)
  - Most MIMO configurations are under 4x4
  - Most reported peak data rates are under 1 Gbps
  - Multi-core PC + GPU + FPGA represents the latest trend for baseband signal processing.

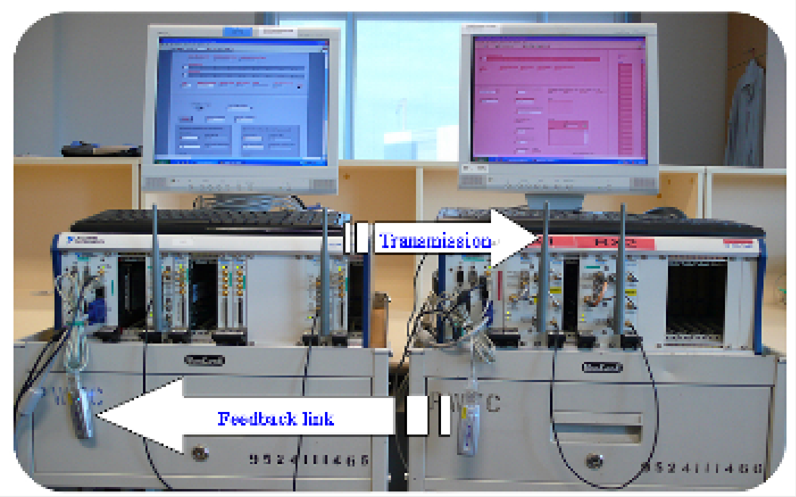
Solution 1: Standard Instruments

- **Build a testbed by integrating PCs and standard radio testing instruments**
  - Use standard instruments for RF signal generation and reception
  - Use PC workstations for baseband signal processing and control
  - Support off-line signal processing in Matlab
  - Could be extended to support real-time signal processing using multi-core, graphic processing unit (GPU), and/or FPGA extensions.
  - Adopted by WiCO



Solution 2: Modular Instruments

- **Build a testbed based on modular instruments**
  - Modular instruments for radio testing provide flexible and convenient integration of modular components for RF, baseband, and power, etc.
  - Compatible with Matlab; Complicated hardware design (e.g., HDL) can be avoided.
  - Suppliers include National Instrument (NI) and Aeroflex.
  - Adopted by WiCO

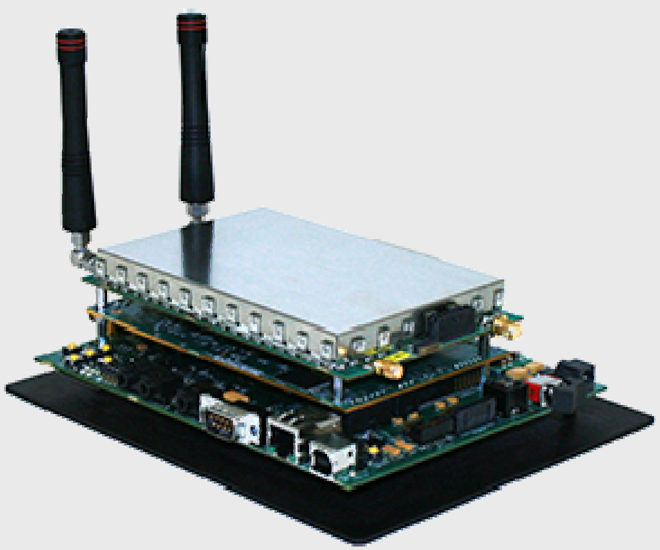


A NI instrument based MIMO-OFDM testbed at Nanyang Technological University, Singapore [http://www.pwtc.eee.ntu.edu.sg/Research/Pages/research_projects_mimo.aspx]

Aeroflex 3020 Series PXI RF Signal Generator

Solution 3: Commercial Testbed

- **Purchase commercial off-the-shelf testbeds**
  - Specialised companies sell commercial software define radio (SDR) testbeds including all components from baseband to RF.
  - Suppliers include Lyrtech and PenTek, etc.
  - The state-of-the-art products can support processing capability equivalent to 1 WiMax BS and 4 GSM BS.

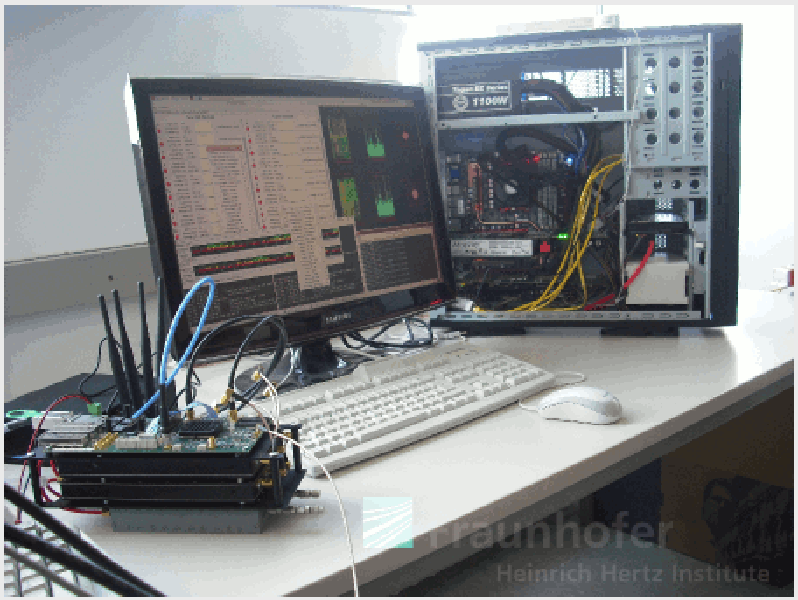


Lyrtech SDR development platform
(www.lyrtech.com)

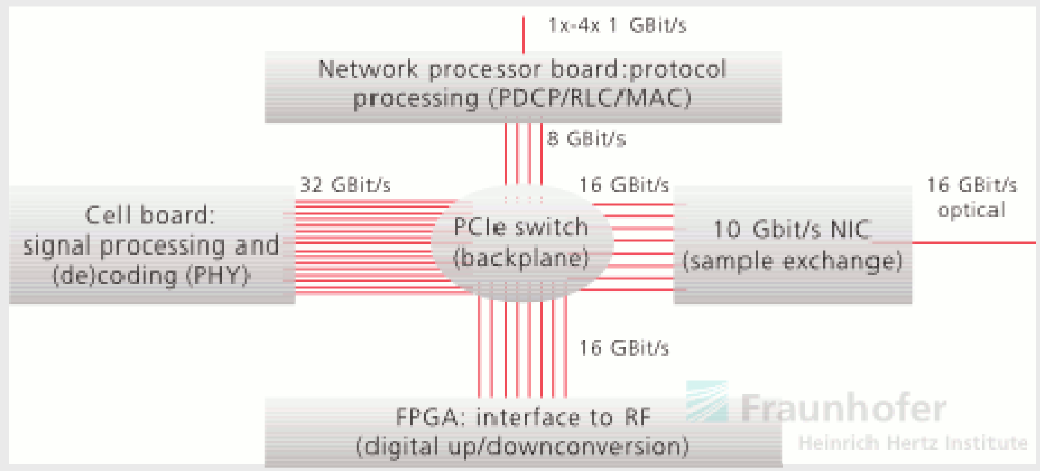
PenTek 7142-428 SDR platform
(www.pentek.com)

Solution 4: Integrated Testbed

- **Integrate the testbed based on commercial off-the-shelf subsystems**
  - Off-the-shelf baseband, RF, and data acquisition subsystems can be purchased and integrated to build a testbed.
  - Different subsystems are commonly integrated through PCIe or PXI interfaces.
  - Adopted by Heinrich Hertz Institute (HHI), Germany



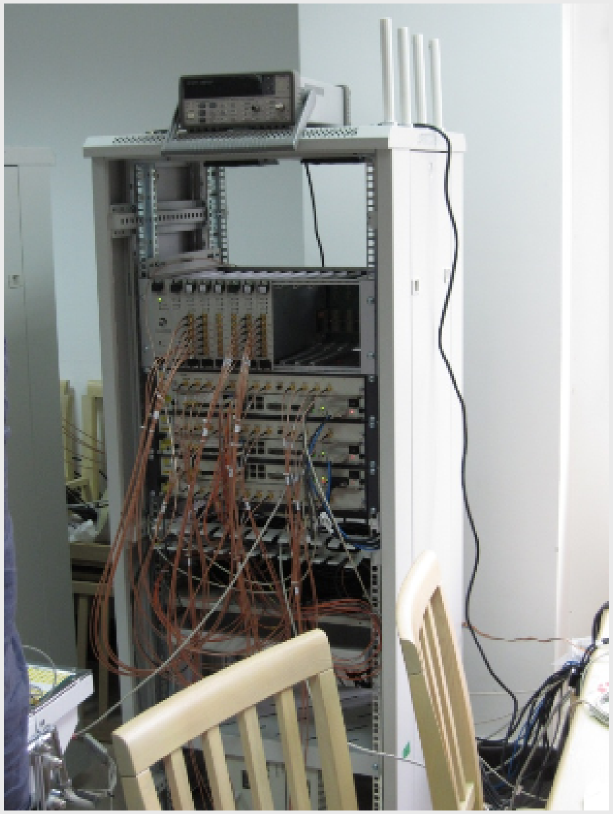
A SDR testbed at HHI, Germany
(www.hhi.fraunhofer.de)



Architecture of the SDR testbed at HHI, Germany
(www.hhi.fraunhofer.de)

Solution 5: Self-designed Testbed

- **Design and produce customised testbed**
  - Design subsystems from baseband to RF and produce highly customised testbed
  - Adopted by Southeast University, China



A Gbps transmission testbed at Southeast University, China

Pros and Cons of Various Solutions

	Performance (e.g, bandwidth, real-time)	Flexibiity (e.g., spectrum, power)	Development Efforts	Cost
1. **Standard Instrument**	Low~Medium	Low~Medium	Low	Medium
2. **Modular Instrument**	Medium	Low~Medium	Low	Medium
3. **Commercial Testbed**	Medium	Low	Low	Medium~High
4. **Integrated Testbed**	Medium	Medium~High	Medium	Medium
5. **Self-designed Testbed**	High	High	High	High

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III. Overview of Existing System Level Testbeds

- **EASY-C (Germany)**
  - **April 2007-Sept 2010, ~47M Euros**
  - **Testbeds**
    - Dresden testbed: 10 sites and 28 sectors, PHY focused, deployed Apr 2009
    - Berlin testbed: 4 sites and 7 sectors, end-to-end demonstration
- **FuTURE (China)**
  - **Project duration: 2001-2010**
    - Phase I (01-03): 4G Transmission schemes
    - Phase II (03-06): Experimental networks
    - Phase III (05-10): Trial and pre-commercial network
  - **Testbeds**
    - Beijing: 2 APs, 2 cells, and 3 UE
    - Shanghai: 6 APs, 3 cells, and 6 UE
- **KDDI (Japan)**
  - Testbed summary: 1 BS, multiple MSs

Comparison of System-Level Testbeds

	EASY-C	FuTURE	KDDI
Centre frequency (GHz)	2.6	3.45	4.5
Bandwidth (MHz)	20	20	DL: 100; UL: 40
Duplex mode	FDD & TDD	FDD & TDD	FDD
Network size	4 BS	6 BS	1 BS
MIMO	2x2/2x4	4x4/4x8	2x2
Peak data rate (Mbps)	150	120	DL: 747; UL: 176
Spectrum efficiency (bit/s/Hz)	1-6	2-10	DL: 7.47; UL: 4.40
Coverage (km)	1.2	1	1.2

Comparison of Research Topics

	EASY-C	FuTURE	KDDI
Coordinated multi-point (CoMP)	✓	✓	
Multi-antenna	✓	✓	✓
Inter-cell Interference management	✓	✓	
Relay functions	✓		
Self-optimizing networks	✓	✓	
Spectrum/carrier aggregation			
Green radio			

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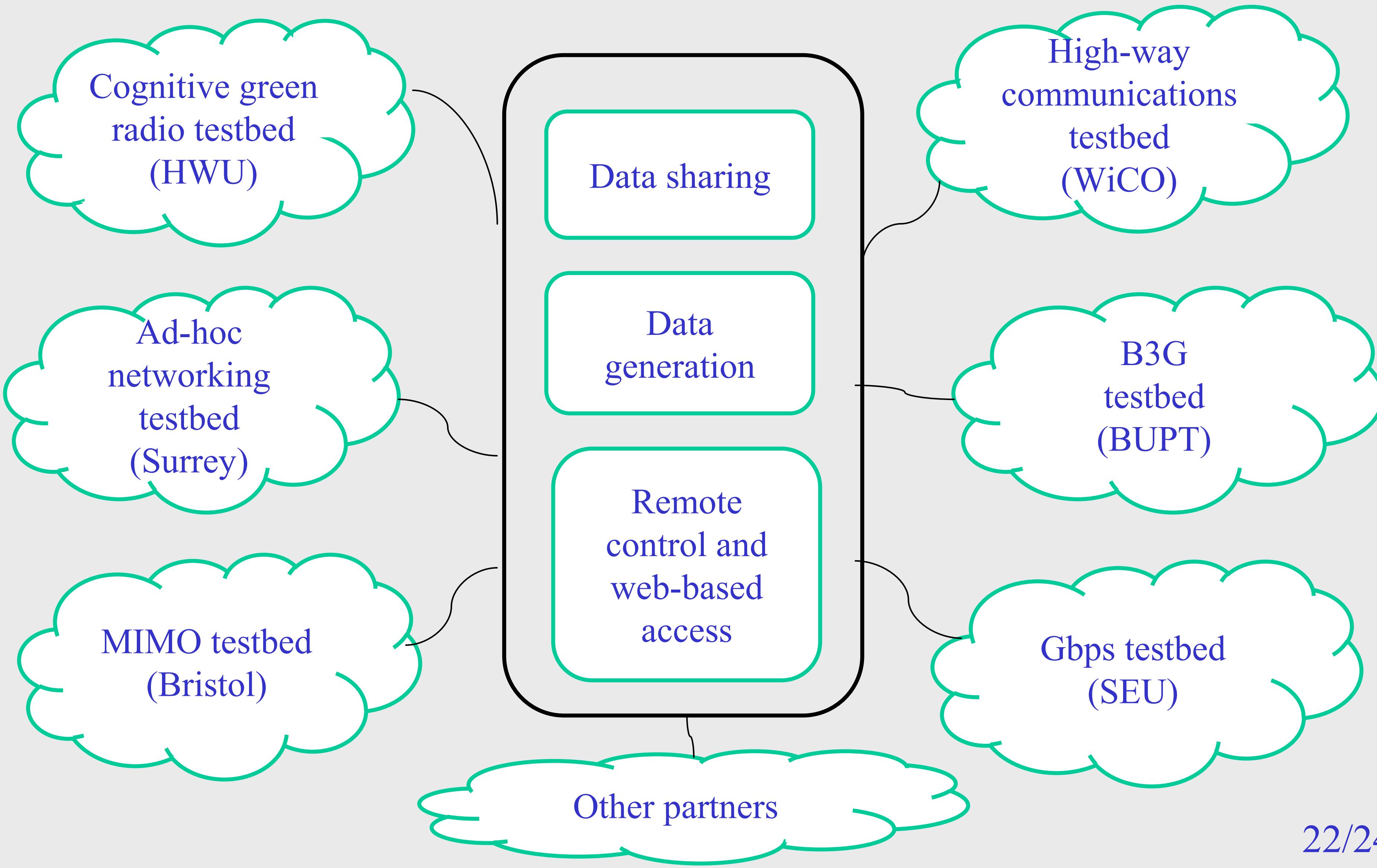
- **Challenge: very limited budget and man power**
  - Budget~ £100k (compared with EASY-C: 47M Euros)
  - No full-time staff
  - Limited experience
- **Proper positioning of the testbed is very important**
  - Understand the demands from the academia and industry
  - Define the scope
    - Physical layer v.s. All layers?
    - Link level v.s. System level?
    - Centralised v.s. Distributed?
    - Real-time v.s. Off-line?
  - Differentiate by features
    - Cognitive radio (e.g., carrier aggregation)?
    - Green radio?
    - Multiple scenarios?

Initial Suggestions for Discussion

- **Link level: A cognitive green radio testbed**
  - Focus on the link level and PHY layer to ensure low-cost
  - **Differentiate from existing testbeds by focusing on two technical features**
    - Spectrum/carrier aggregation (cognitive radio)
    - Green radio
  - Address the interests of both the academia and industry?
- **System level: A virtual UK-China testbed**
  - **There are many small scale testbeds in the UK and China**
    - Cover various layers and scenarios (micro-cell, high-way, femto-cell, etc.)
    - Have different features
    - Some testbeds support remote access and control
  - **A virtual testbed that integrates various distributed testbeds via Internet**
    - Specify the virtual interface among testbeds (e.g., data structure)
    - Emphasis on "off-line emulation" rather than "real time demonstration"
    - Differentiate by heterogeneity and multiple scenarios

Illustration of Concept



Summary & Future Work

- **Summary**
  - We have to set up a testbed and we have very limited budget and man power.
  - It is important to understand current demands for testbeds in academia and industry.
  - It is important for the new testbed to differentiate itself from the many existing ones.
  - A link-level testbed featuring cognitive green radio technologies is feasible.
  - A system-level virtual testbed featuring heterogeneous scenarios may be possible.
- **Future work**
  - Seek wider opinions from academia and industry regarding the UC4G testbed.
  - Visit BUPT, and possibly other UC4G partners.
  - Draft a testbed feasibility study report.

Thanks: A Small Testbed Focus Group at HWU

- **Dr Cheng-Xiang Wang** (Supervisor): Project management and supervision
- **Dr Xuemin Hong**: Feasibility and architecture
- **MSc students**
  - **Robert**: FPGA-based baseband processing
    - System level FPGA design methodology: PC/GPU ⇔ FPGA ⇔ Equipments/RF
    - LTE OFDM modem
  - **Yu**: GPU/CPU-based baseband processing
    - Accelerate LTE simulation using GPU/multi-core CPU
    - GPU-Matlab interface and parallel signal processing in Matlab
  - **Ting**: Equipments and LTE testing
    - Operate R&S equipments
    - LTE RF and baseband signal testing
  - **Osama**: Carrier aggregation
    - Track the carrier aggregation features in IMT-Advanced systems
    - Implement a simulation model for carrier-aggregation based on LTE

?

Thank you for your attention!

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