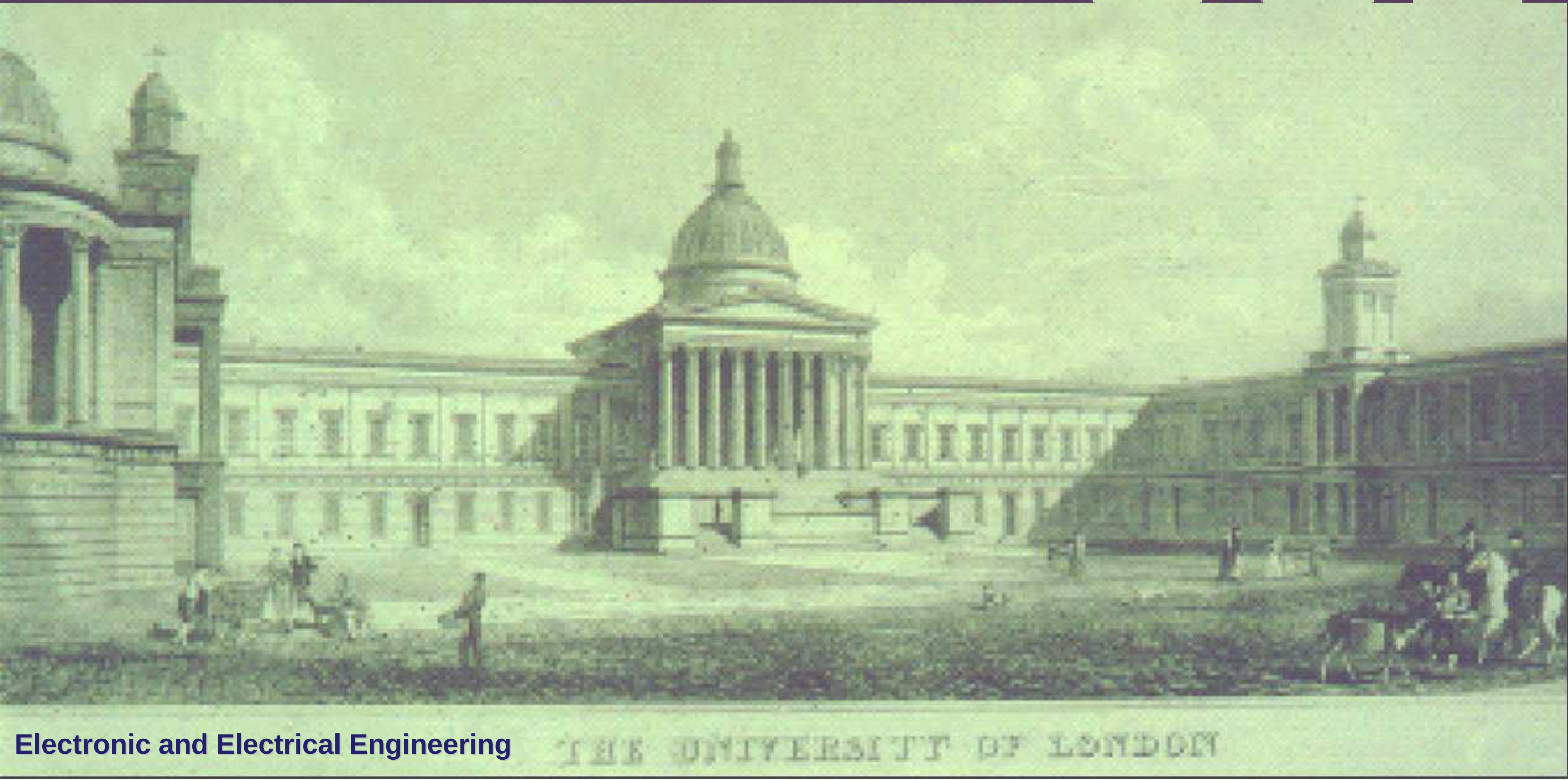
UK-China Science Bridges: R&D on 4G Wireless Mobile Communications



Electronic and Electrical Engineering

University College London

- Founded in 1826, the original University of London, the third oldest university in England
- The first university in England to admit students of any race, class or religion (1826), and the first to welcome women on equal terms with men (1878)
- Nobel Prizes have been awarded to 20 academics and graduates
- 72 departments, 3800+ academics, ~19000 students, more than 30% international students from 130 countries – the largest university in London

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Telecom Pioneers

UCL

Alexander Graham Bell

–Inventor of the telephone

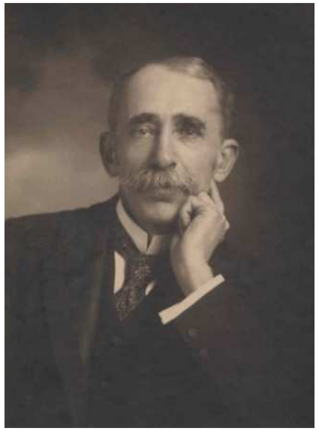
–Studied Vocal Anatomy at UCL 1868-1870

Sir John Ambrose Fleming

–Inventor of the Thermionic Valve, LH rule

–Founder, First Professor and Head of Department of Electrical Engineering UCL

–Designed Marconi's transmitter station for the first transatlantic radio broadcast in 1901



Hidetsugu Yagi (1886-1976)

Guglielmo Marconi

–Pioneer of Radio Communications

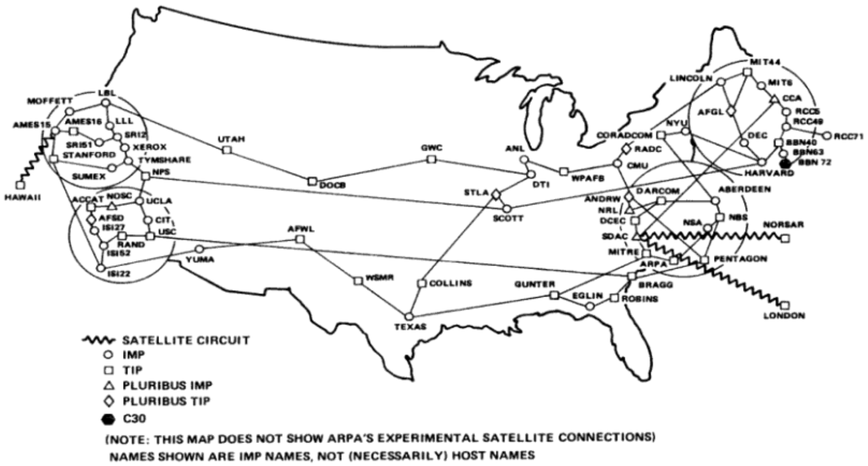
–Prof Sir A Fleming of UCL designed the transatlantic radio station for Marconi which transmitted between Poldhu, Cornwall and Newfoundland, Canada on the 12th Dec 1901

Hidetsugu Yagi

–Co-inventor of the Yagi-Uda Antenna, now the norm for television reception

–Postgraduate researcher in EE Department at UCL

ARPANET GEOGRAPHIC MAP, OCTOBER 1980



–First ARPANET Node outside the US

Sir John Pender

–Established the company that installed the first working transatlantic telegraph cable; Founder of Cable and Wireless

–Fleming provided technical assistance – hence the Pender Chair and Pender Electrical Laboratories at UCL

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Electronic and Electrical Engineering

UCL

- Founded in 1885, the first EE department in England
- 320 undergraduates, 290 MSc students, 70 research students, 30 research staff, and 30 academic staff
- Five research groups
  - Photonics
  - Optical Networks
  - Sensors, Systems and Circuits
  - Electronic Materials and Devices
  - Communications and Information Systems
- Strong collaborations with industry (Strategic Partner of British Telecom)
- London Centre for Nanotechnology (Collaboration with Imperial College)

–Engineering Building

London Centre for Nanotechnology

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Research Activities and Collaboration Opportunities

Research Areas in Communications

UCL

Wireless systems

- Spectrally efficient multi-carrier systems
- Modulation techniques
- MAC protocol design
- QoS wireless multimedia
- Multi-system coexistence
- Software and Cognitive radio
- Sensor networks

Optical systems

- Optical access networks
- Radio over Fibre (WLAN and WiMAx)
- Radio over PONs
- Multi Gbit/s circuit design
- Optical CDMA

IP networks

- Overlay networks
- Network traffic monitoring and modelling
- QoS and IP architectures
- Network management and services
- Context-aware Networks and Services

–Research outputs:

–80 High-impact journal publications since 2001

–High citation score and several awards

–Industrial/standards

adoption of designs

–Our work covers:

–Theoretical/mathematical

–Experimental

–Industrial

–Business

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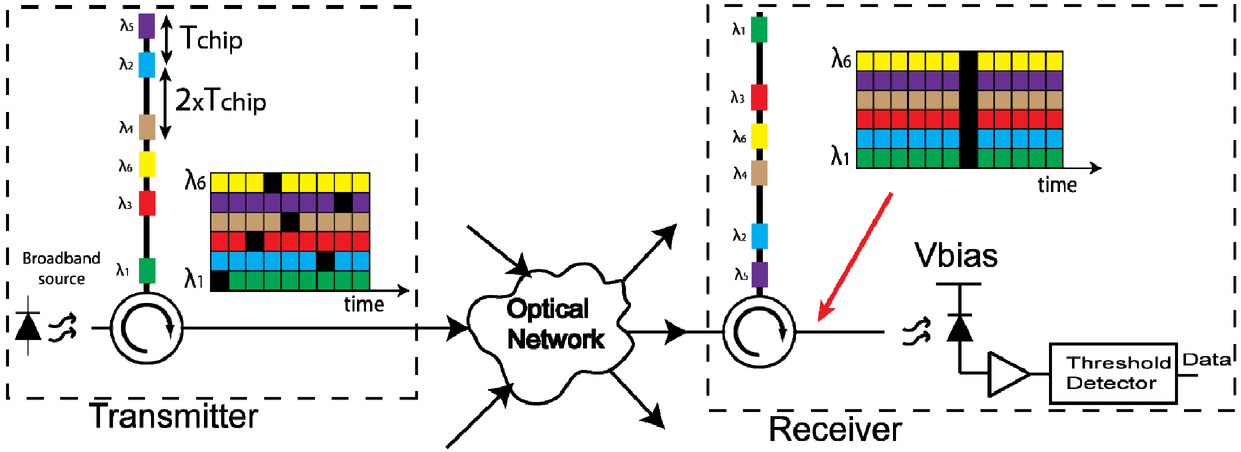
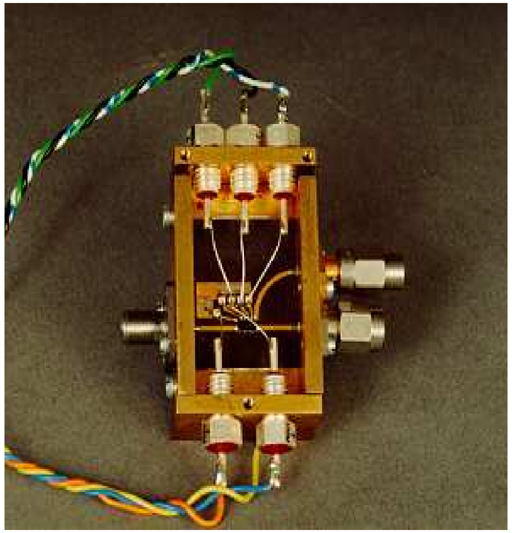
High-speed Communication Circuits

- New circuit topologies to enable 40+ Gbit/s core and access systems
- World first 40 GBit/s receiver in 1997
- Deal with the "electronic bottleneck" and replace optical components by electronic ones
- Effectively analogue electronics techniques for digital applications
- Collaborations with Nokia-Siemens, University of Aveiro, CERN, and Nortel

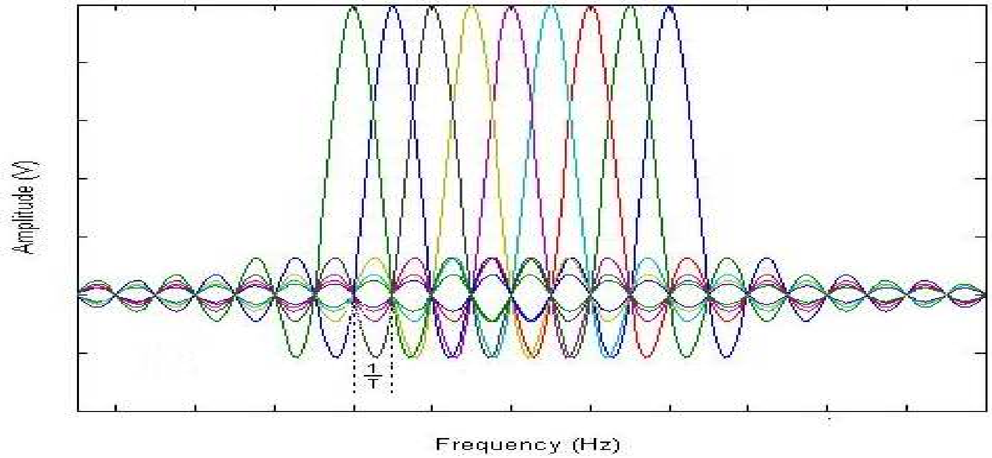


ASSEMBLED PROTOTYPE

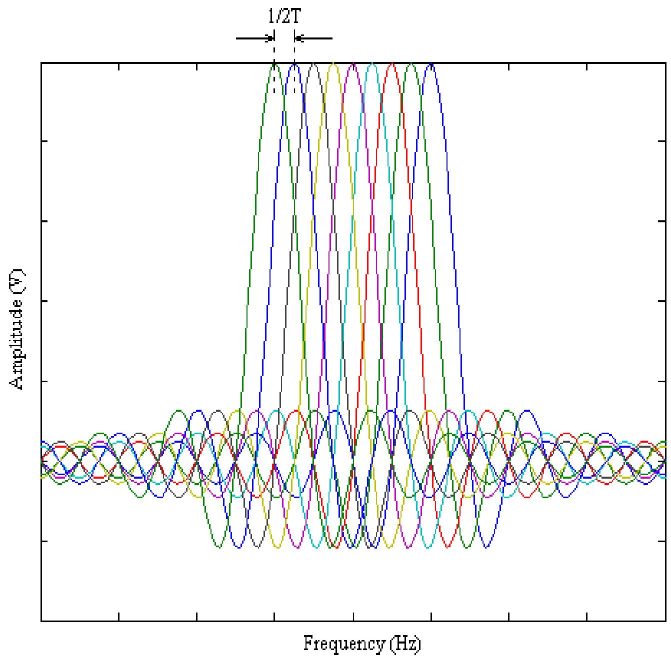


Bandwidth Efficient Multi-Carrier Systems

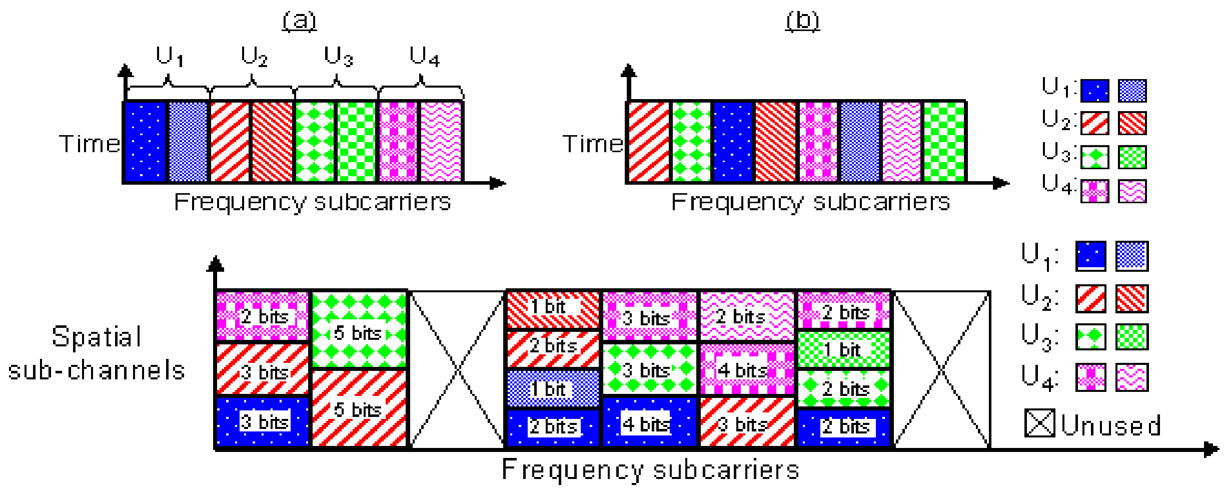
- New modulation formats with the aim of improving spectral (and power) efficiency (energy per bit)
- Design of new receiver structures
- Studies of complexity
- Practical implementation
- Collaboration with Alps Electrics and the University of Porto-Portugal
- Previous collaboration and funding from Nokia (OFDM and EDGE) and Anritsu (multi-carrier systems)



Normal OFDM Signals



Fast OFDM Signals



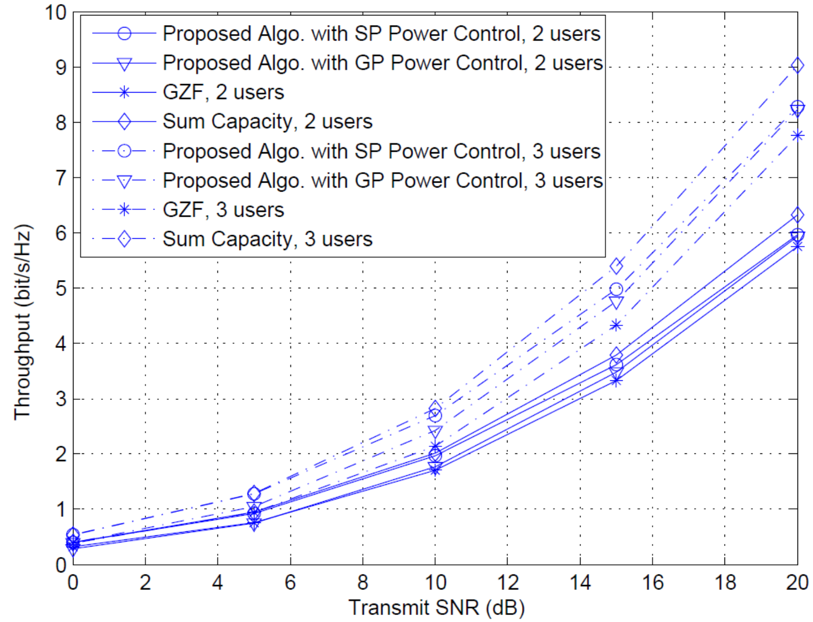
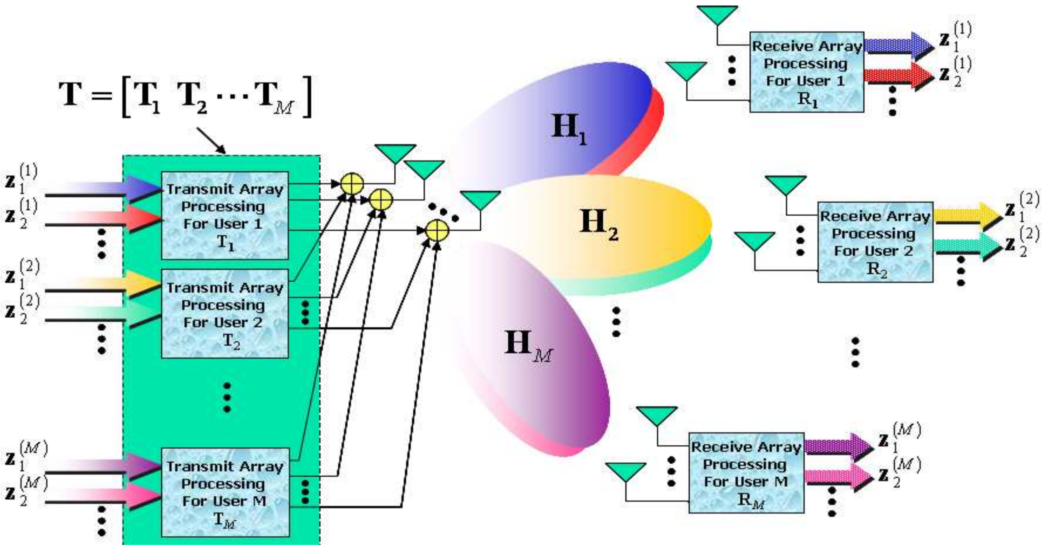
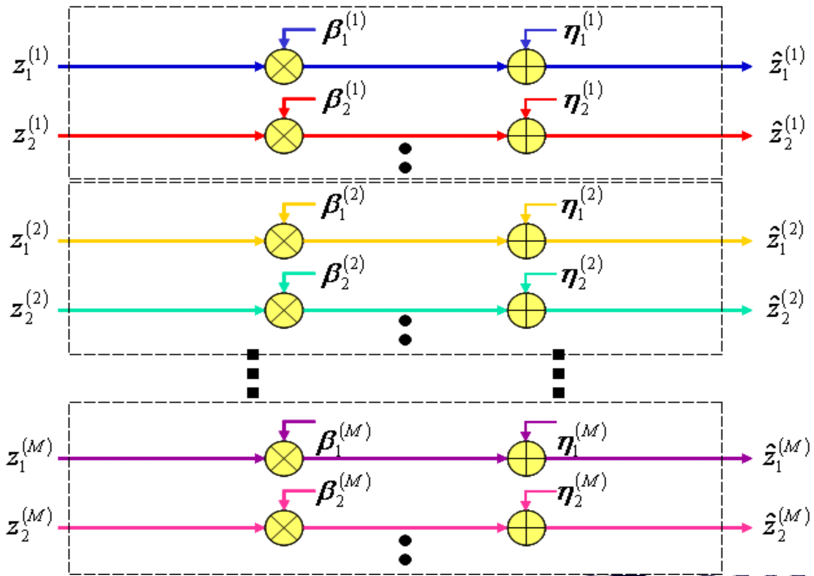


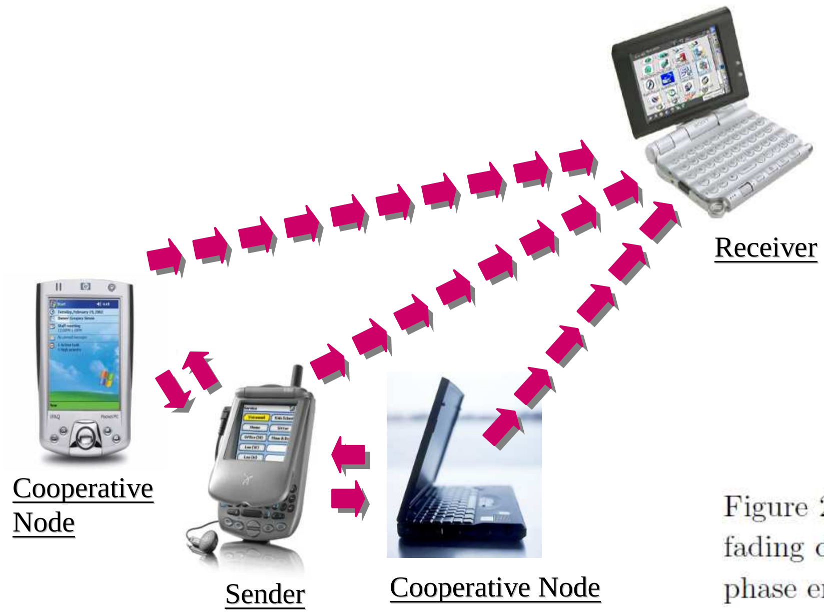
Figure 1: Throughput results for 2-user $(2, 2)$ and 3-user $(3, 2)$ systems.

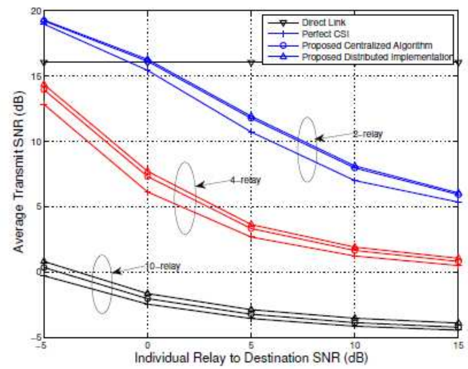
With CSIT, generalised zeroforcing (GZF) beamforming decomposes a multiuser MIMO downlink system into parallel uncoupled spatial streams



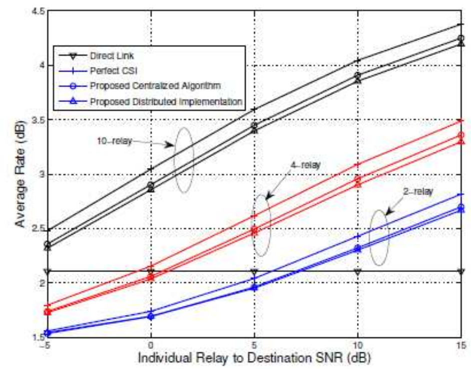


Mobile terminals can cooperate to form a virtual MIMO channel for capacity enhancement and power saving



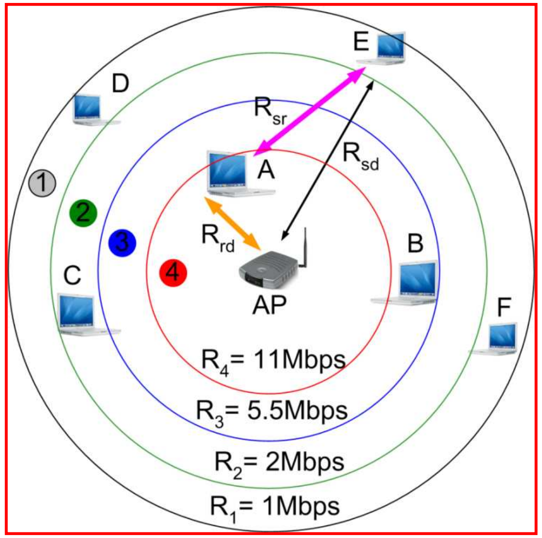


(a) The average normalized SNR at s

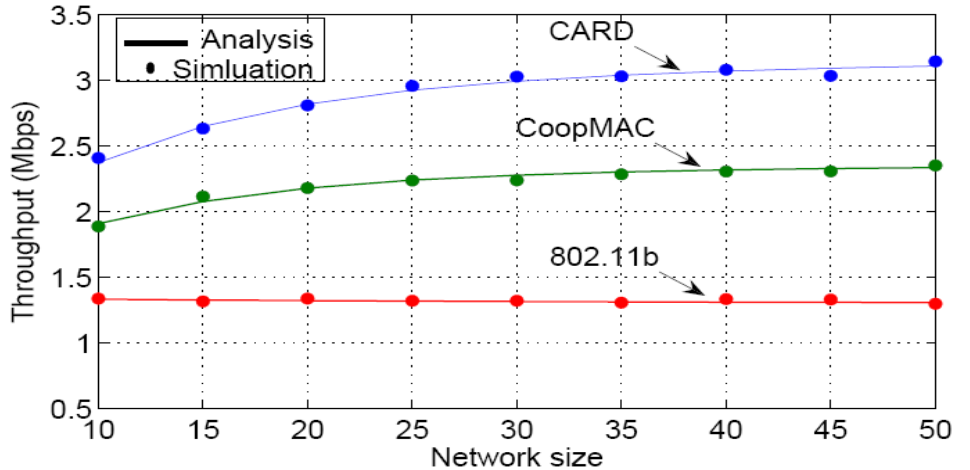


(b) The average achievable rate

Figure 2: Performance results against the individual relay-to-destination SNR at 1% outage for Rayleigh fading channels with $\mathrm{E}[|g_m|^2] = 1$, $\mathrm{E}[|h_m|^2] = \mathrm{E}[|h_0|^2] = 0.1\ \forall m$, $\frac{\rho^2}{\mathrm{E}[|h_0|^2]} = 0.001$, and $r_0 = 1$ bps/Hz. The phase errors, $\{\phi_m\}$, are considered to be independent and uniformly distributed from $-30°$ to $30°$.



Cooperative Access with Relay's Data (CARD) for multi-rate high-density wireless local area networks (WLANs)



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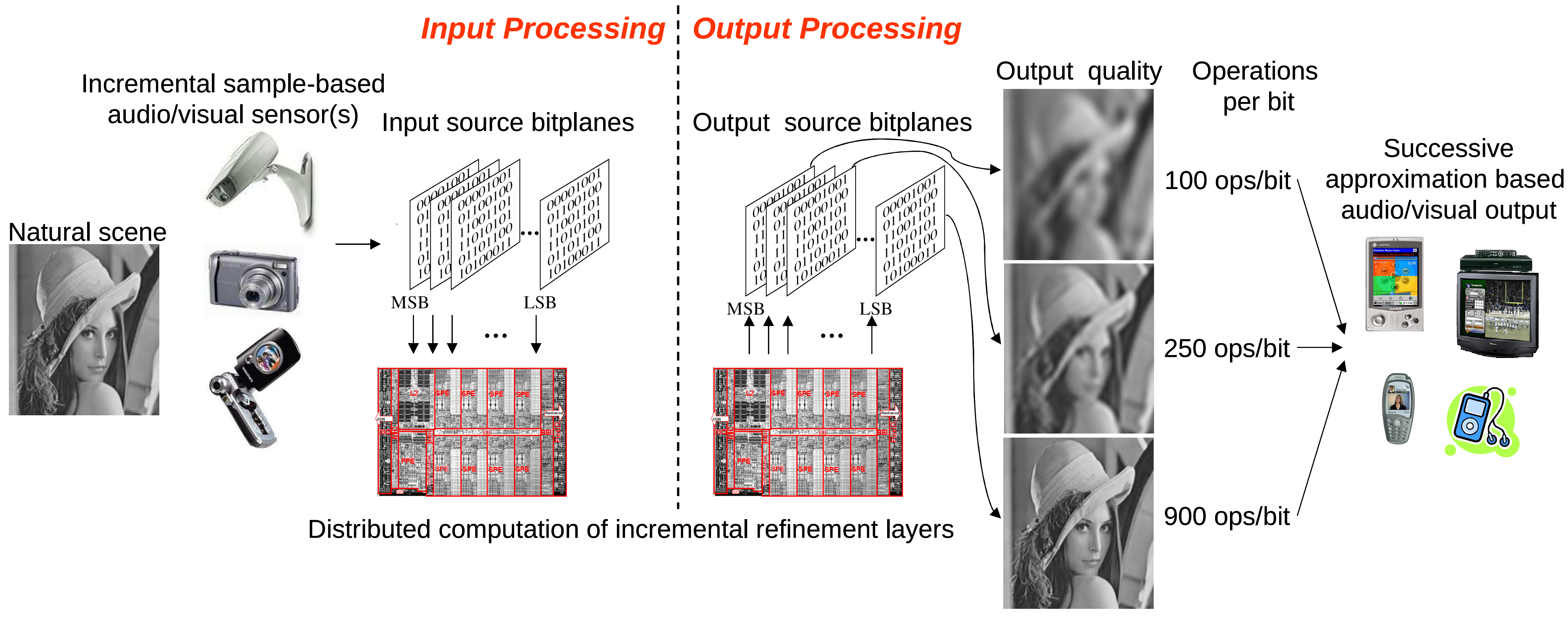
Multimedia Systems Adaptation



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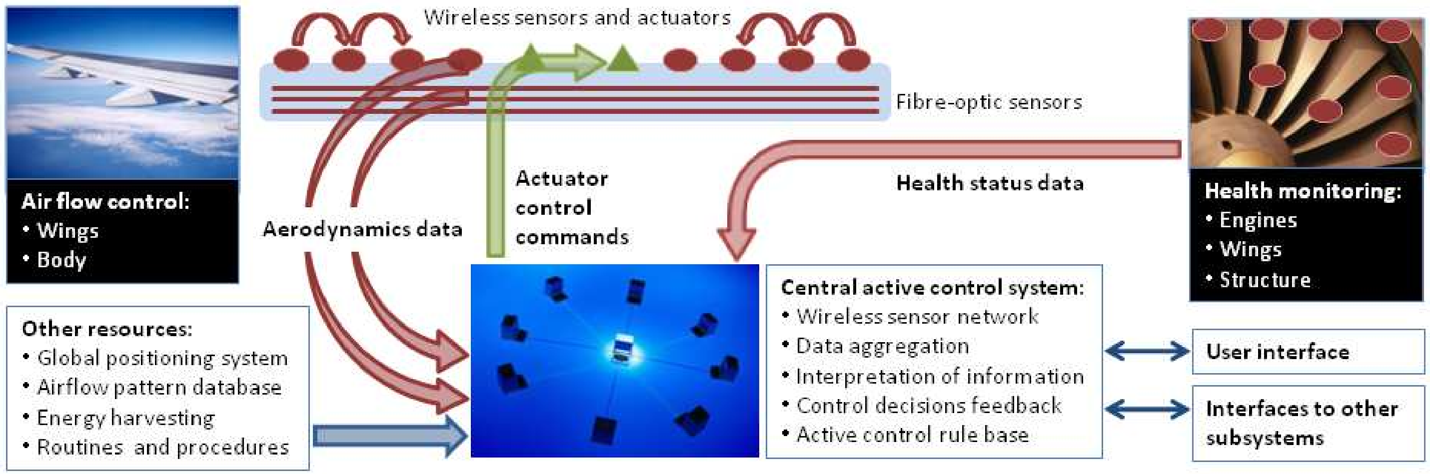
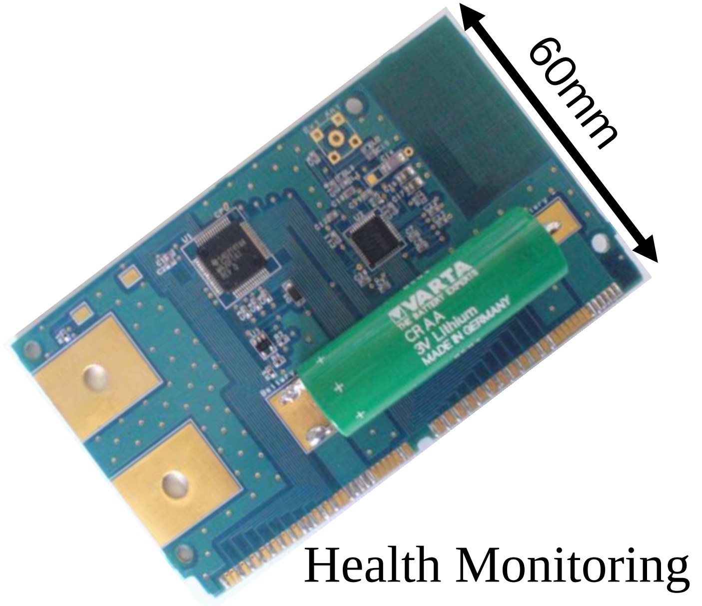
Wireless Sensor Networks and Applications

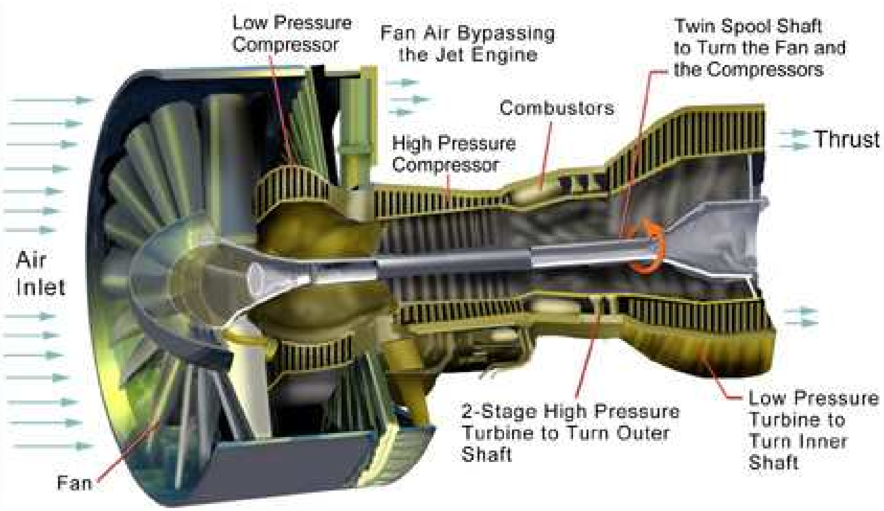
UCL





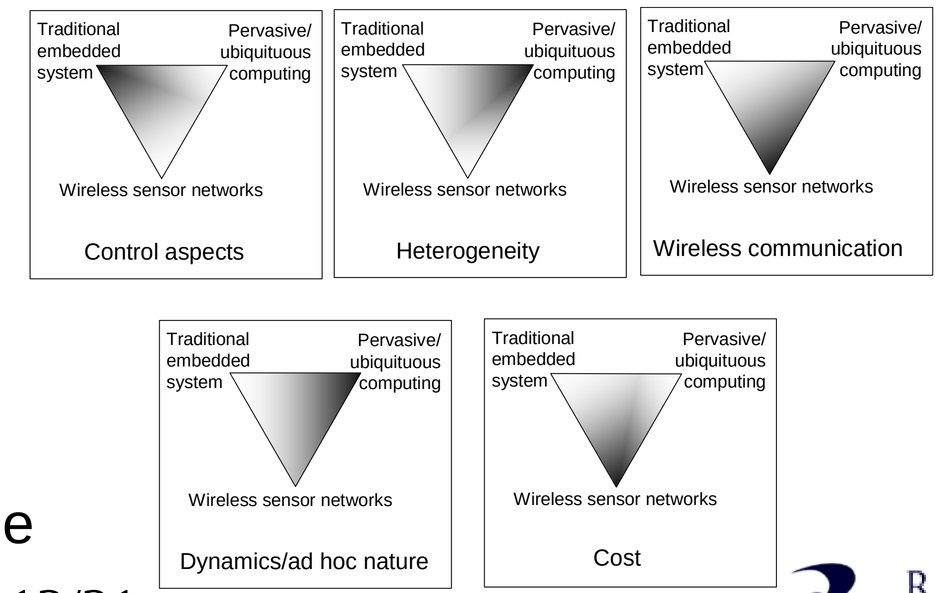
Health Monitoring

Active Flow Control and Skin Friction Drag Reduction for Aircraft



Data Acquisition in Gas Turbine Engine Testing

Cooperating Objects



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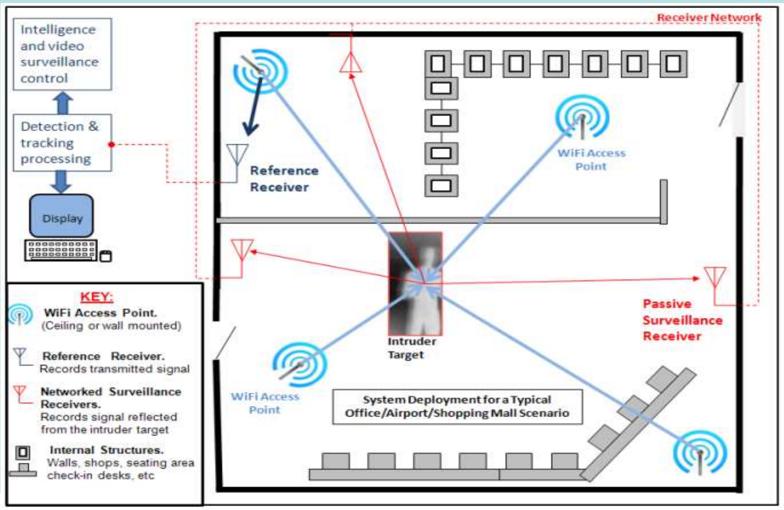
Detection & Tracking using WiFi Networks

UCL

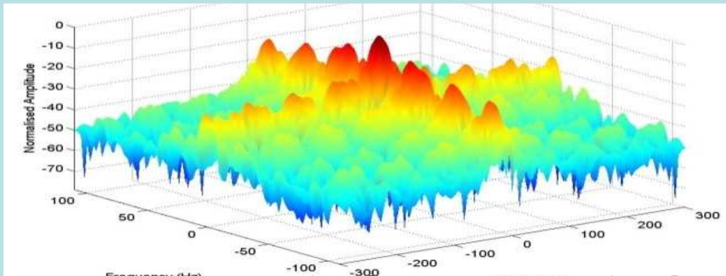
Introduction

- 802.11 Wireless networks provide a ubiquitous source of signals for exploitation in surveillance applications, using passive radar technology, which has no impact to 802.11 WiFi network use.
- Non-cooperative target detection.
- Targets can be detected through walls & at night
- The system provides 360˚coverage.
- The use of existing transmitters means the system is low cost.
- A network of receivers permits discrimination of closely spaced targets.

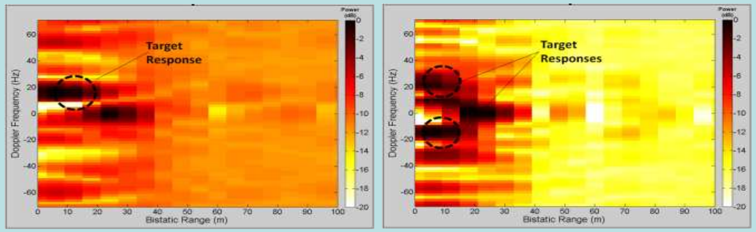


Target Detection in High Clutter

- Target detection experiments were conducted within an indoor office environment to simulate a real-life environment with significant clutter and multipath components.
- UCL's multistatic netted radar system (NETRAD) was used as a passive receiver
- Targets consisted on personnel targets moving at running and walking paces.
- Theoretical analysis on the signals received from the WiFi access point were also carried out to determine potential performance characteristicss of the system.



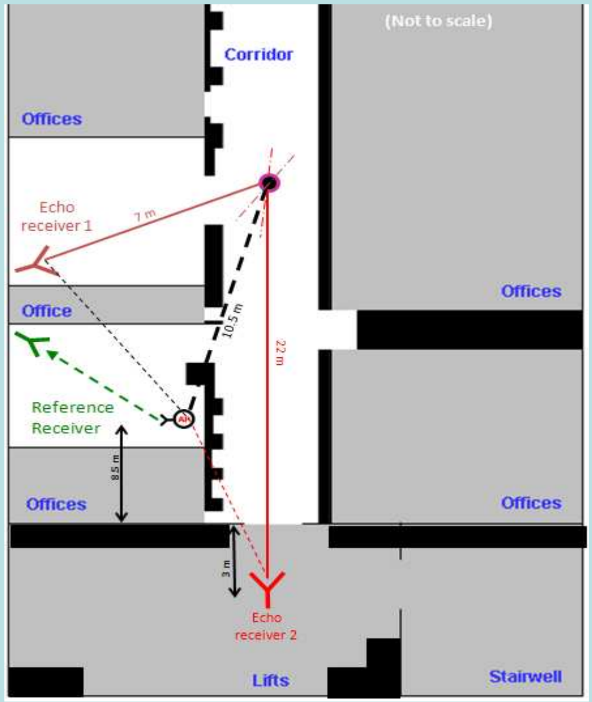
Ambiguity Function for a 802.11 Tx signal



Results of target detections for:

–A walking person (left)

–Two people walking in opposite directions (right)



Experimental Setup at UCL

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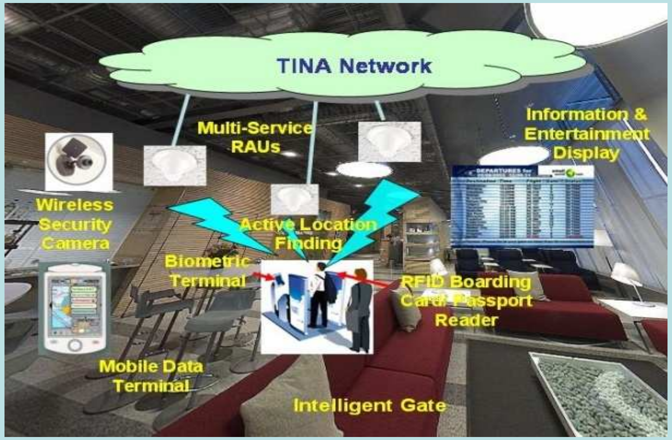
RFID Indoor Locating System - TINA

UCL

Introduction

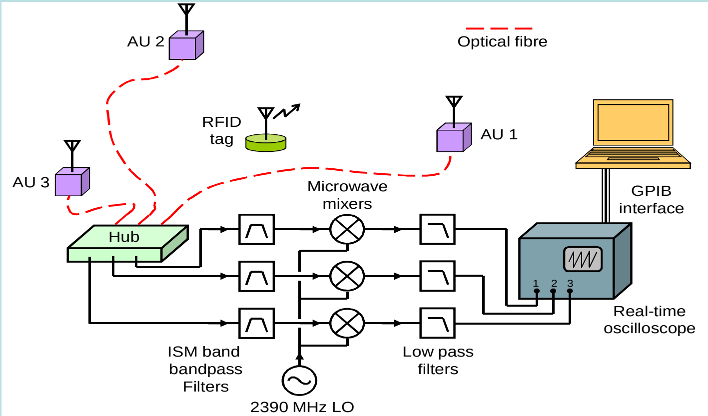
To develop a seamless wireless/wired ubiquitous infrastructure with high levels of computational power to meet the environment of Intelligent Airport.



– Active RFID boarding pass
– Antenna units deployed around the airport
–RF-over-fibre backbone
–Central location estimator
–Frequency – 2.4GHz ISM band
–Bandwidth – 83.5MHz
–Chirp duration – 1 us, 10 us, 80 us
–Reading range – 20 meters
–Location estimation accuracy – 1 m
–Radiation power – 0 dBm

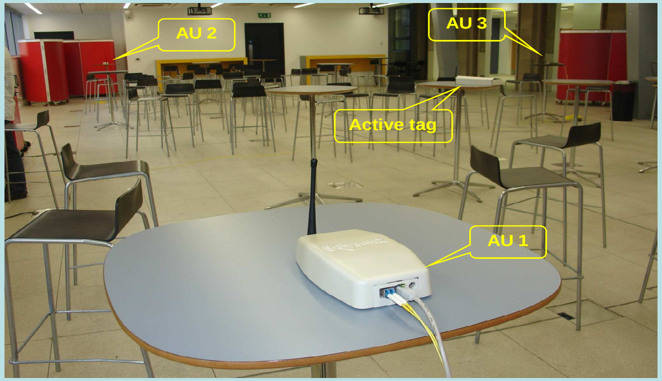
Indoor tracking demonstrator

Each cell of the location system will be monitored by 3 base stations for 2-D tracking, or 4 base stations for 3-D tracking. Received RF signals are converted into optical signals



Location tracking hardware implementation

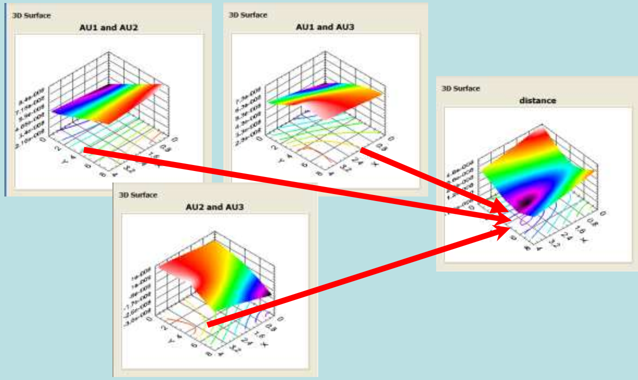
Three Antenna Units (AUs) were employed to serve one cell. The tag signals received by the AUs were transported back to a central hub via three 40m long single-mode fibres. to the 10–93.5 MHz band. This allowed the three channels of signal to be digitised directly with a real-time oscilloscope for subsequent data processing.



Real-time locating experiment

TDOA localization algorithm

Given the size of a room, a simple mapping method, instead of solving tedious hyperbolic functions, can be used to find out the location of a target tag.



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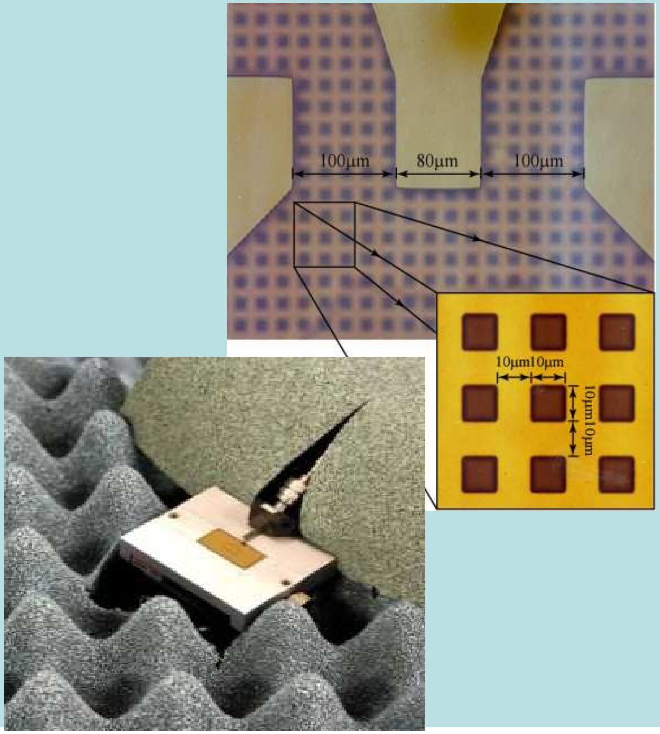
Planar Antenna Designs

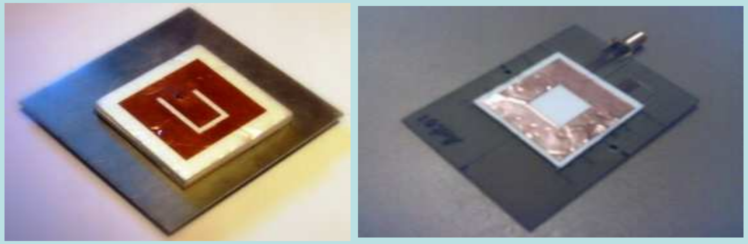
UCL

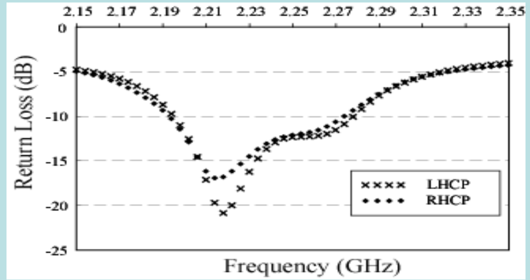
Millimetre-wave Coplanar Patch Antennas

- Easy integration with photonic and mm-wave devices with CPW outputs.
- Break through the fabrication challenges in layering low-k dielectric materials which is desirable in antenna application, onto silicon wafer.
- Operating frequency: Ka band

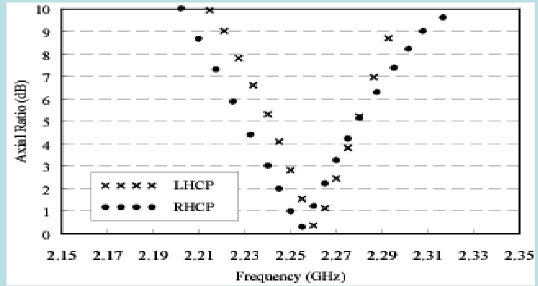


Polarization adaptive antennas



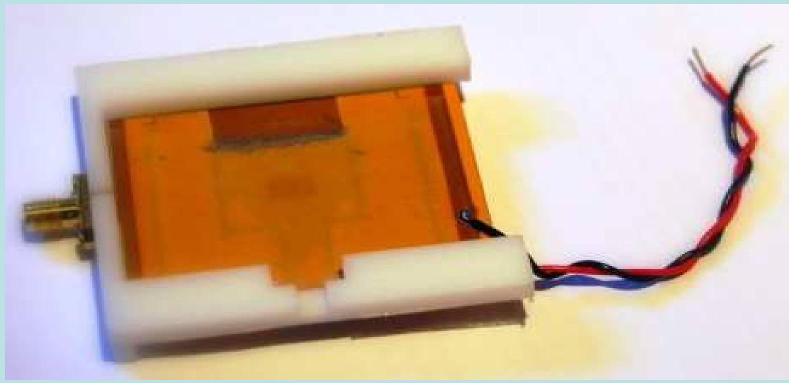


- Can be easily switched between LH & RH circular polarisation by using a high isolation RF switch
- Simply and low cost design
- CP excitation by proximity coupling



Liquid Crystal antennas

- Operate at high frequency, for instance X-band.
- 10% of variation in operating frequency can be achieved by controlling the basing voltage of the liquid crystal.



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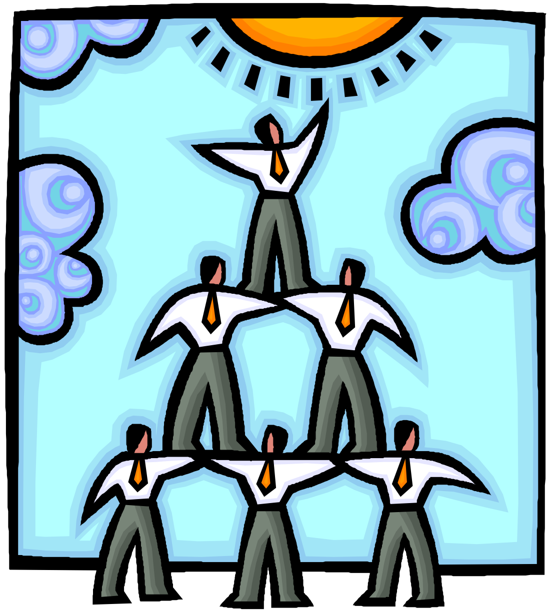
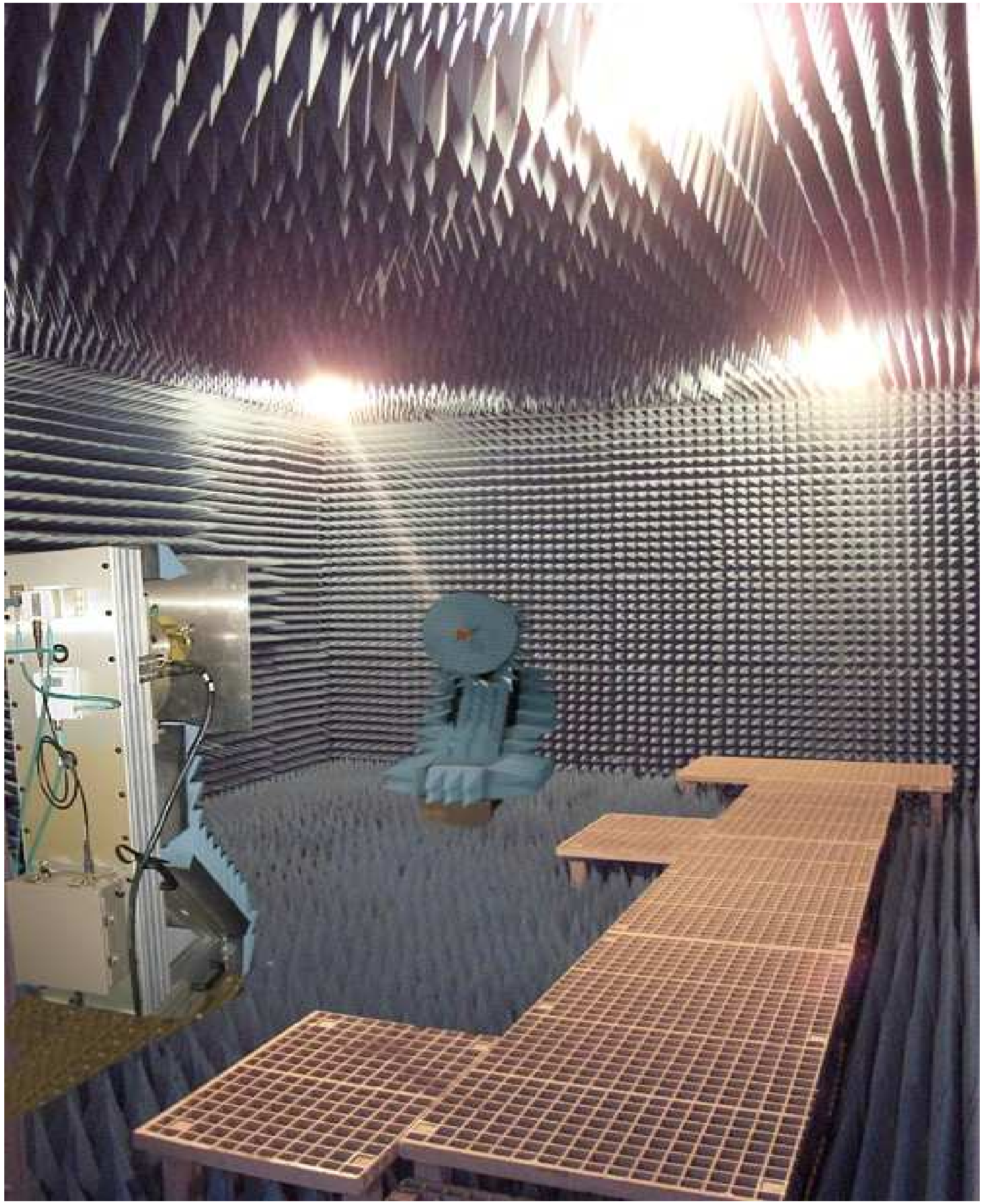
Advanced Equipments and Research Facilities



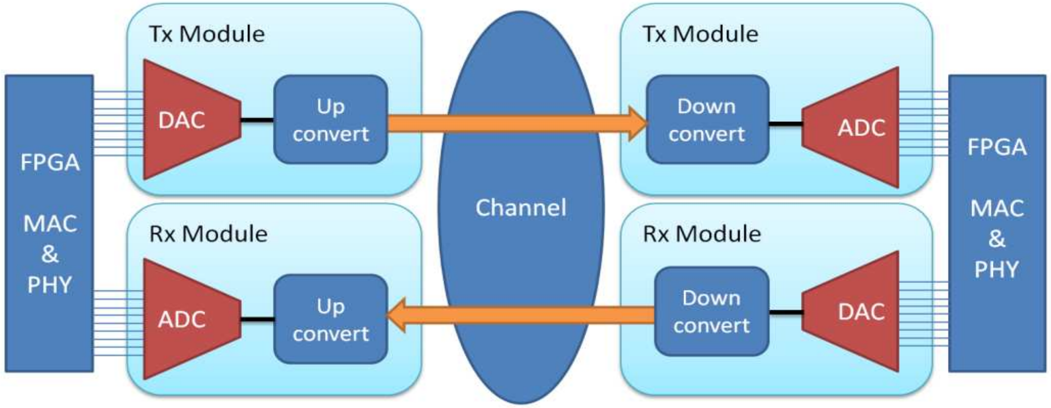
Spherical Near-Filed Scanning Antenna Chamber

- Qualified over 2 - 40 GHz
- -100 dB isolation
- Best facility of its kind in a UK university
- Valuable for experimental evaluation of antennas

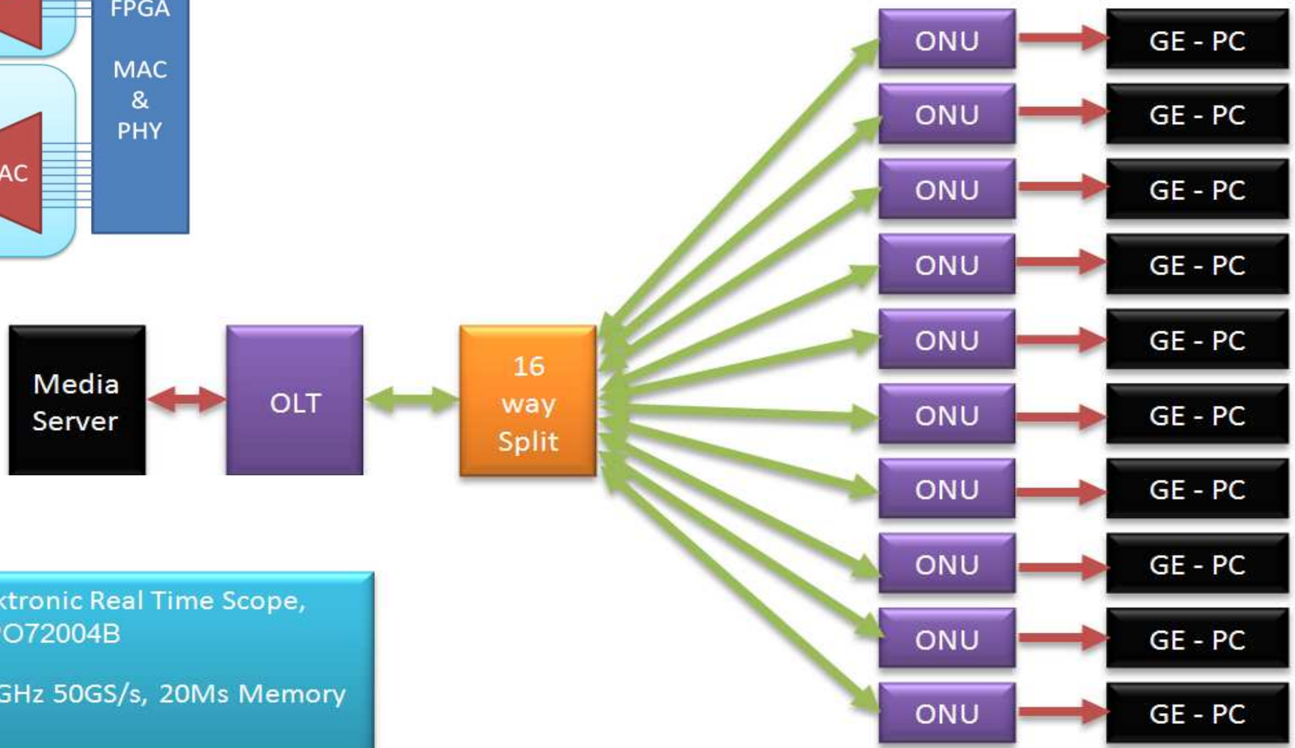


CONNET Testbed

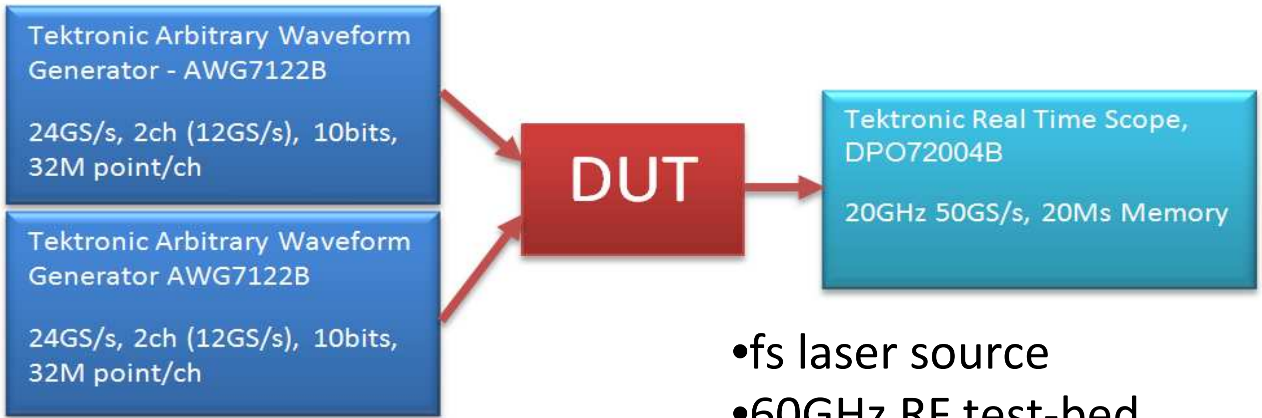
Wireless PHY and MAC Emulation



EPON Network Testbed

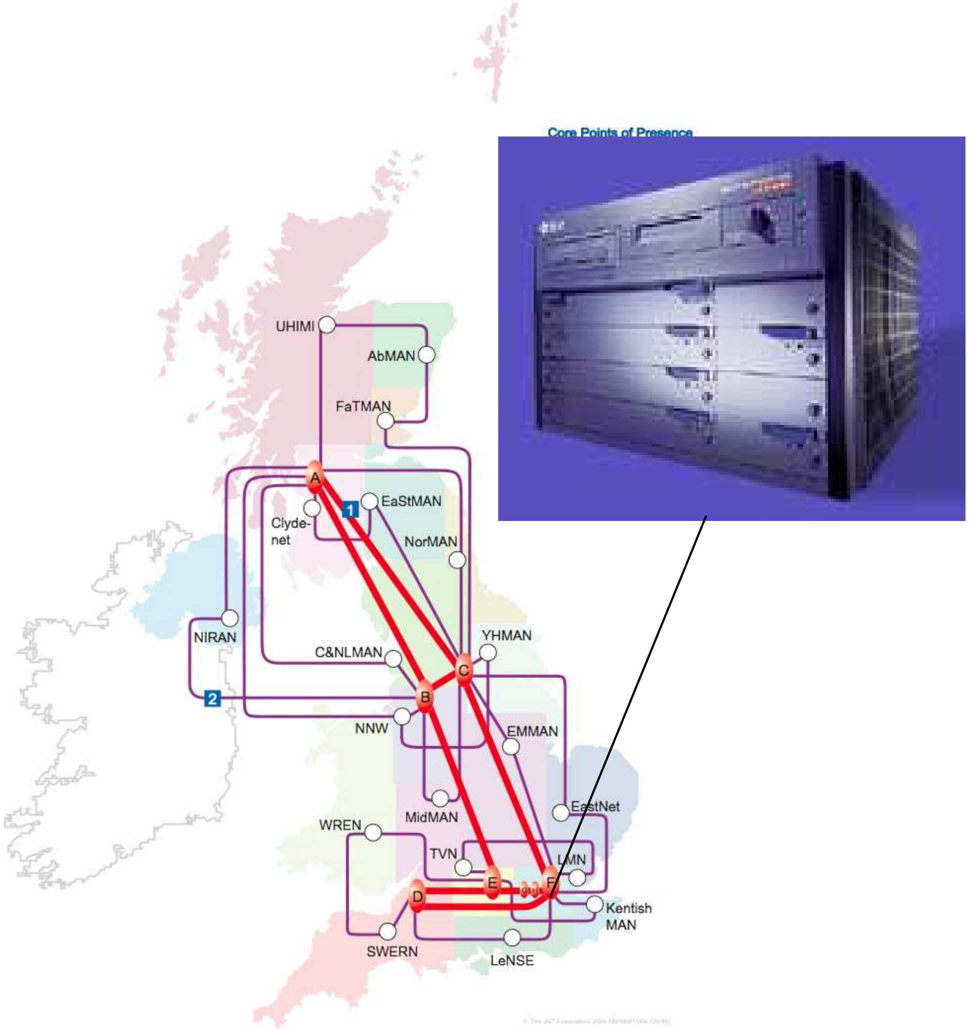


Arbitrary Signal Generation and Analysis



- fs laser source
- 60GHz RF test-bed
- 10pm Optical spectrum analysis

Internet Traffic Measurement and Modelling



- The largest repository in the world of measured Internet data, at 10Gbits/s
- Traffic modelling and analysis
- Network routing and traffic engineering optimisation
- Future Internet
- Next Generation Networks

Research Collaborations on 4G Communications

UCL

Theory

- Differentiated QoS and resilience
- Multimedia stream characterisation
- Multi-Gbit wireless systems: modulation and coding; spectral- and power-efficiency
- Cooperative communications, relay networks and wireless mesh networks
- Cognitive radio and dynamic spectrum access
- Information theory and cross-layer design and optimisation
- Multiuser communications theory
- Performance analysis of MIMO-OFDM systems

Application

- Heterogeneous and scalable access solutions covering wireless, optical and copper access
- Integrated backhaul to support very high bandwidth radio services
- Cross-layer design of access networks
- Content adaptation for heterogeneous devices and networks
- New infrastructures, topologies and circuits
- Service-oriented deployment and management of wireless sensor networks
- Optimization for MIMO antenna and relay selection
- Antenna Design and Optimisation
- RFID and WiFi tracking applications

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Thank you!

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