
# The INtelligent Airport (TINA)

## A Self-Organising, Wired/Wireless Converged Machine

**Ian White and Richard Penty, Cambridge University Engineering Department**
**Jon Crowcroft, Cambridge University Computer Laboratory**
**Jaafar Elmirghani, University of Leeds**
**and Alwyn Seeds and Paul Brennan, University College London**

***Presentation to Networking and Information Services for Innovative Air Transport Services***


# TINA Industrial Partners

Strong industrial support from complementary partners

| | |
|---|---|
| BAA | Airport operator, end user: demonstrator planning |
| LAING O'ROURKE | Airport construction: airport design and application context |
| BOEING® PHANTOM WORKS | Aerospace Manufacturer |
| tyco a vital part of your world | Electronics supplier to aerospace |
| Red-M | Systems integrator: deployment scenarios and RF propagation planning |
| ERICSSON TAKING YOU FORWARD | Network supplier: converged communications systems expertise |
| zinwave | RoF network equipment manufacturer |
| MOTOROLA | Equipment supplier: RFID expertise and equipment donation |


# Motivation

### *Service Growth and Opportunities:*

Airport passenger volumes are currently growing rapidly (8.7% growth of Hong Kong airport, Sept ’06)

Proliferation of new processing and information services causing considerable growth in complexity of airport systems

### *Efficiency:*

Existing aviation infrastructure close to saturation

~10% of the total delays in European air transport are caused by delayed passengers and luggage costing some €150M each year

### *Safety:*

Demand for safer and more secure aviation

Evacuation / search and rescue procedures (poor visibility)

### *Security:*

Need for enhanced security, particularly visible measures to act as deterrent and reassure public

UCL


# The INtelligent Airport

***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location
3. To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment
4. To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services
5. In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies


# The INtelligent Airport

***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

***Project Objectives***:

1. **To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations**
2. To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location
3. To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment
4. To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services
5. In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies

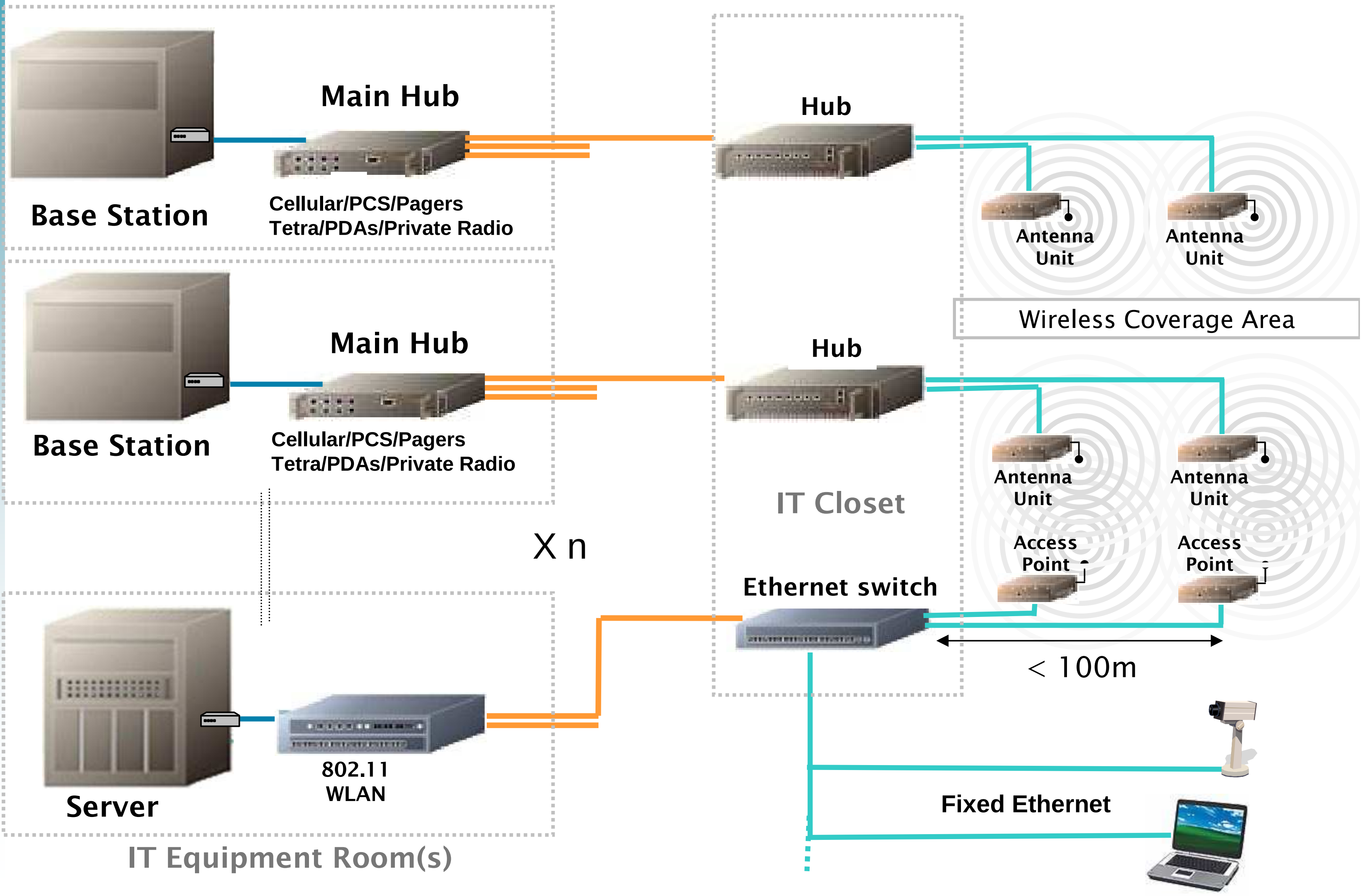

# The Applications Challenge

Aggregate Mean Rate 65.7 Gb/s, assumed Aggregate Peak Rate 100 Gb/s

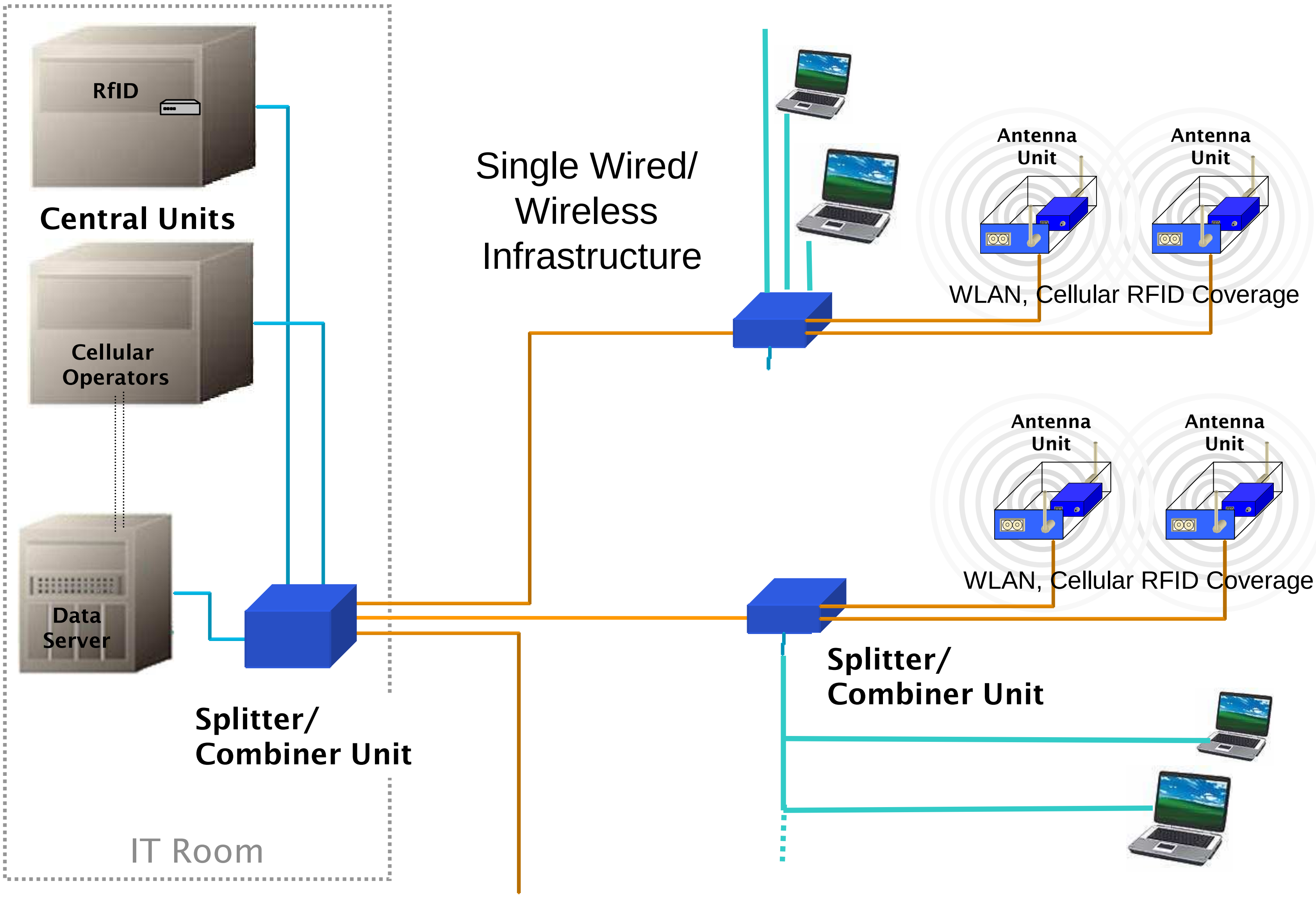
And

*The system must be upgradeable, scalable, resilient and secure*

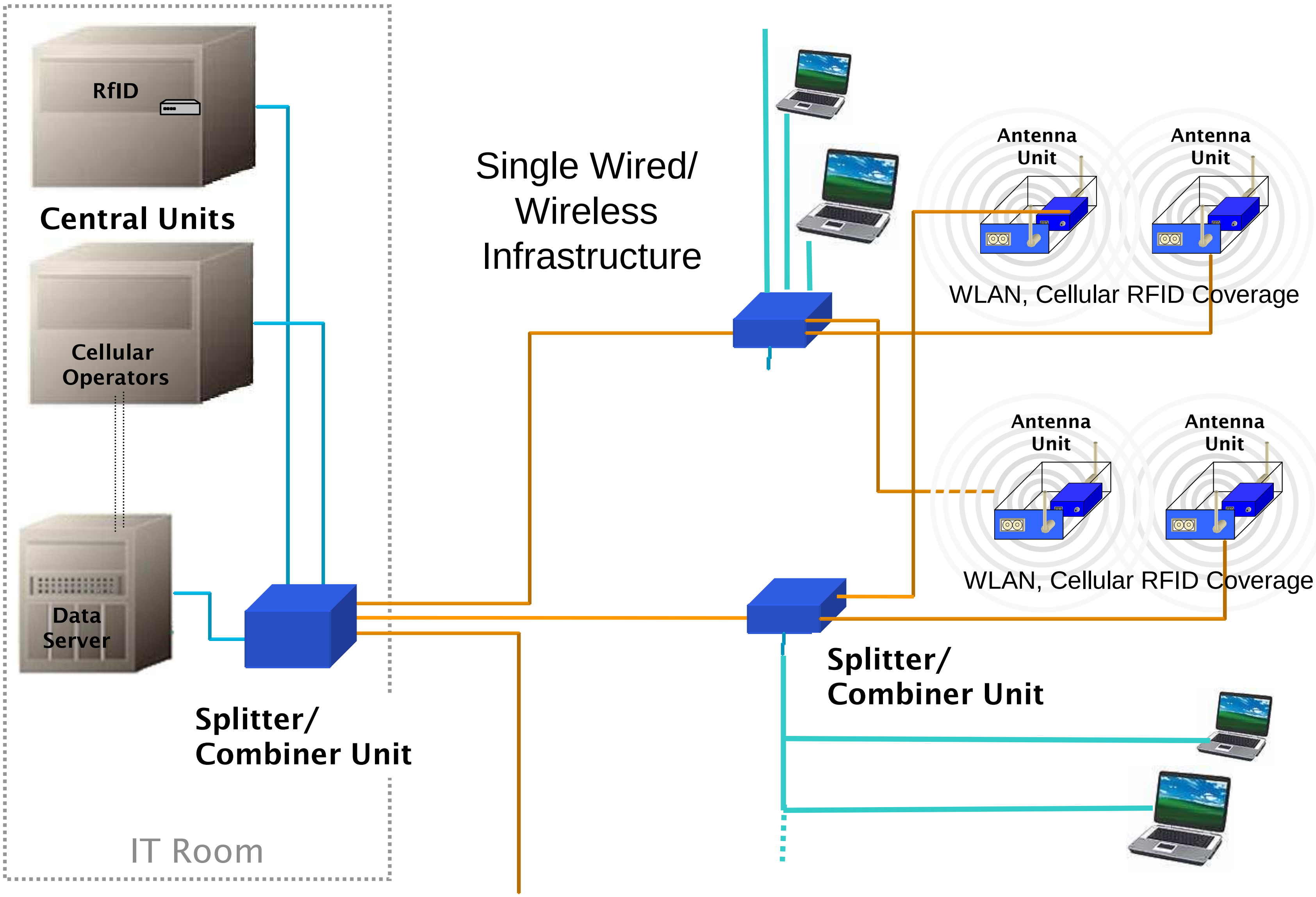
# Current Airport Installations

# First Phase Airport Network

# First Phase Airport Network


# The INtelligent Airport

***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. **To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location**
3. To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment
4. To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services
5. In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies


# The INtelligent Airport

***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. **To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location**

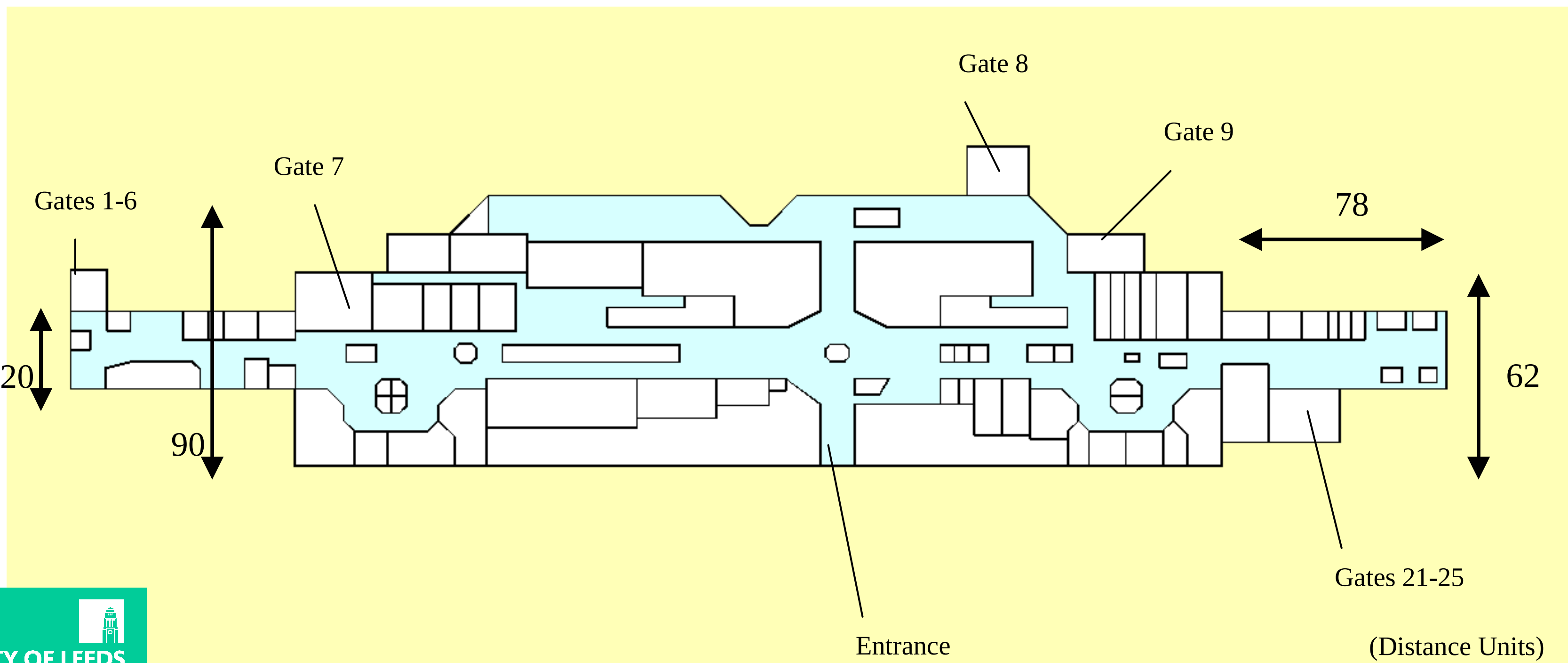
***- To do this we need to understand how people use airports***
***- And where their communication requirements are***
***- The first aspect of the work is therefore to develop a flow model***

# Heathrow Terminal 4: Departures



# T4 Layout used for Flow Model

***Purpose:*** To model passenger flow in a realistic airport layout (T4/T5) and therefore be able to estimate the communications bandwidth needed in different parts of the airport at different times and under different conditions.


UNIVERSITY OF LEEDS


# TINA Passenger flow model

- There is a single entry point in T4 through a security check point.
- There are 25 gates and about 70 shops of varying size
- The node (passenger) speed is 1 m/s
- Passenger arrivals are Poisson distributed at the entrance
- Departure is through one of the 25 gates, departures within a 2 hour duration

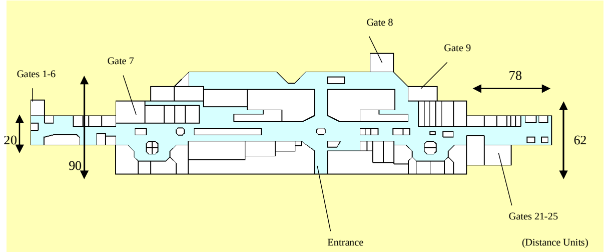
  Flights Timetable:
  - 07.00 h    Gate 1, 124 passengers
  - 07.20 h    Gate 7,    100 passengers
  - 07.40 h    Gate 8,    120 passengers
  - 08.00 h    Gates 21, 85 passengers
- The gates are equally likely and the choice of destination gate is uniformly distributed among the 25 gates.

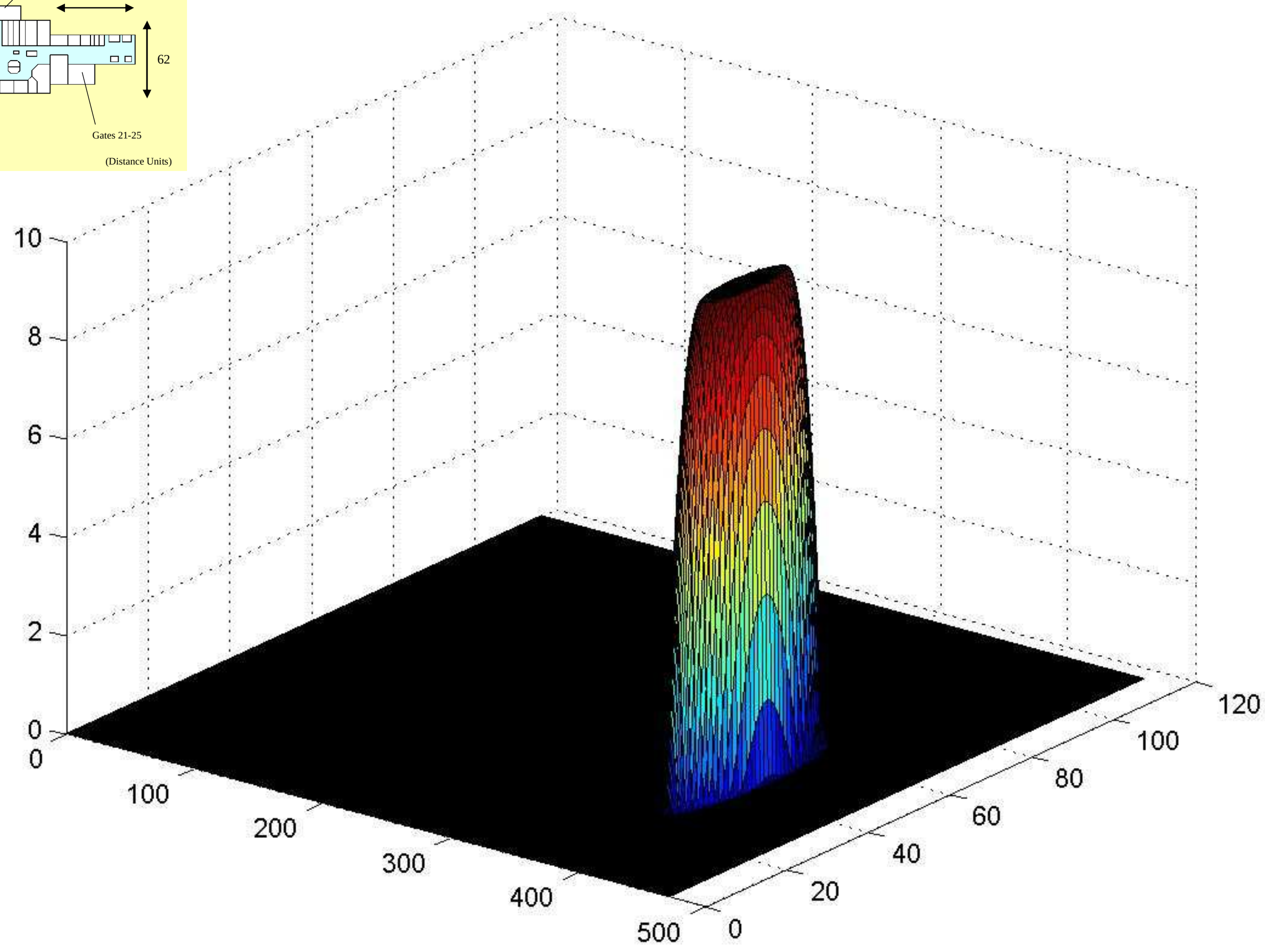

# Passenger flow model

- Passengers make a number of stops at locations such as shops after entry.
- The number of stops is assumed Gaussian distributed with a mean of 3 stops and a standard deviation of 0.5 (ie most passengers do 1.5 to 4.5 stops at the shops).
- Passenger motion is graph based with corridors and shop entry points representing branching points (with different branching probabilities).
- Passenger motion within a shop is assumed to follow a random walk.
- Passengers use voice, data and video calls, all with different Pareto distributions and passenger usage distributions

UNIVERSITY OF LEEDS


# Communication Bandwidth requirements updates every 5 minutes




UNIVERSITY OF LEEDS

# The INtelligent Airport


***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

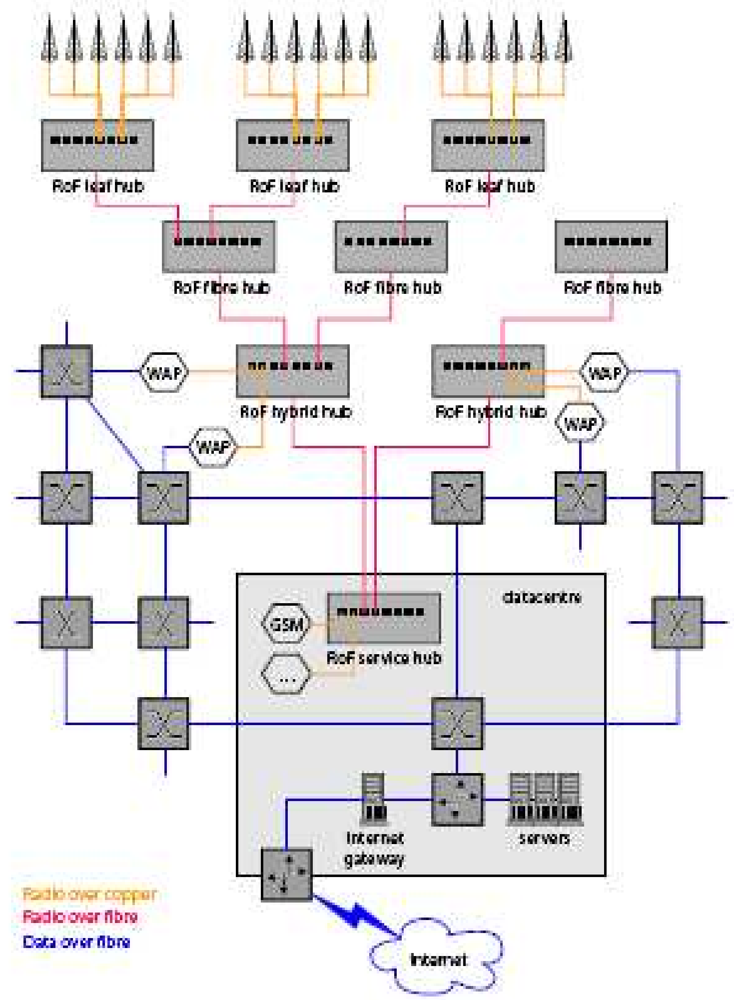
***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location
3. **To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment**
4. To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services
5. In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies


# The Network Scenario

- The Airport Network must be protocol agnostic
  - Ethernet good base as it is ubiquitous, but
  - Poor scalability
    - *RSTP makes inefficient use of the network resources**
- Our solution: A Modified Ethernet which must:
  - be compatible with standard Ethernet end nodes
  - route more intelligently (shortest paths; failure avoidance)
  - ***be more scalable***

Airport network topology




UNIVERSITY OF CAMBRIDGE

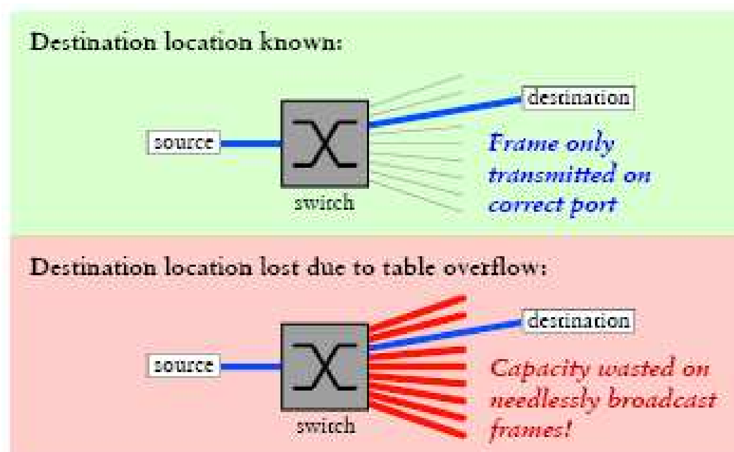

# Scalability issue

- One scalability issue (of many): MAC address tables
  - The source address of every frame passing through a switch is recorded
  - Builds up a table of where on the network each node is
  - Fixed capacity ~8000 addresses
  - If the table fills, bad things happen
    - At best, frames are flooded throughout the network
    - At worst, data is lost

## One Specific Problem: Address Tables

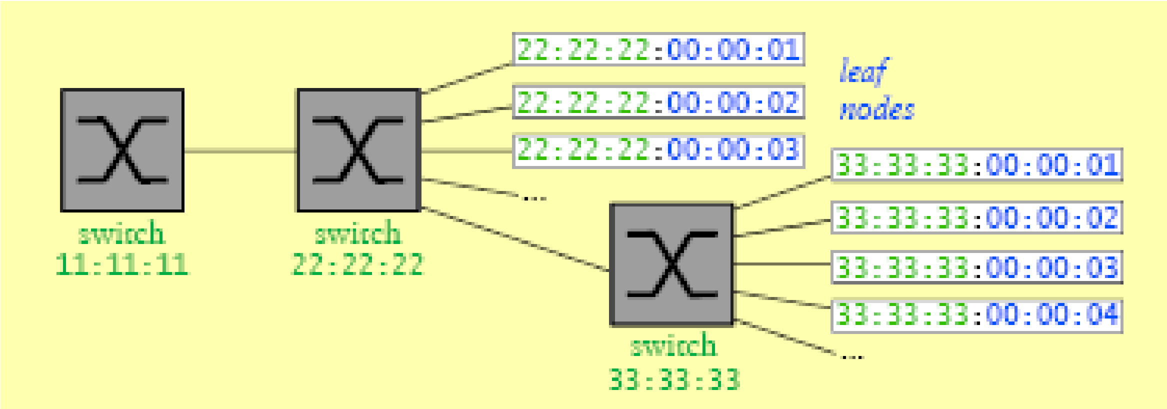
| MAC address | Port |
|---|---|
| 01:23:45:67:89:ab | 12 |
| 00:a1:b2:c3:d4:e5 | 16 |
| ... | ... |

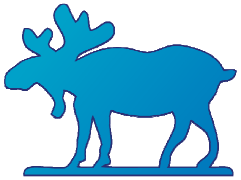
- Maintained by every switch
- Automatically learned
- Table capacity ~8000 addresses
- Full table means broadcast ☹



# The solution: MOOSE

*Multi-layer Origin-Organised Scalable Ethernet*

- Introduce hierarchy into MAC addresses
  - switch ID **:** node ID
- Addresses rewritten by switches
- Switches only need track switch IDs not entire addresses
- Limit now ~8000 switches not ~8000 nodes
  - Say 100 nodes connected to each switch
  - => 100 fold scalability improvement

***Transparent to standard Ethernet end nodes***

***Now being implemented in LINUX***

- Contribution made to the official bridge-utils package

UNIVERSITY OF CAMBRIDGE

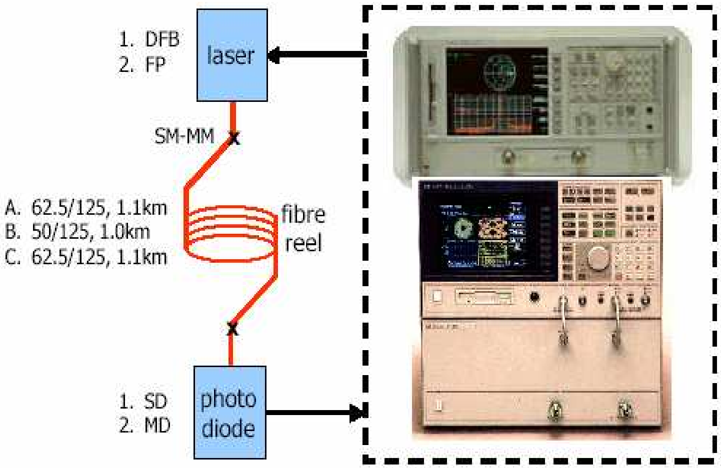
# The INtelligent Airport

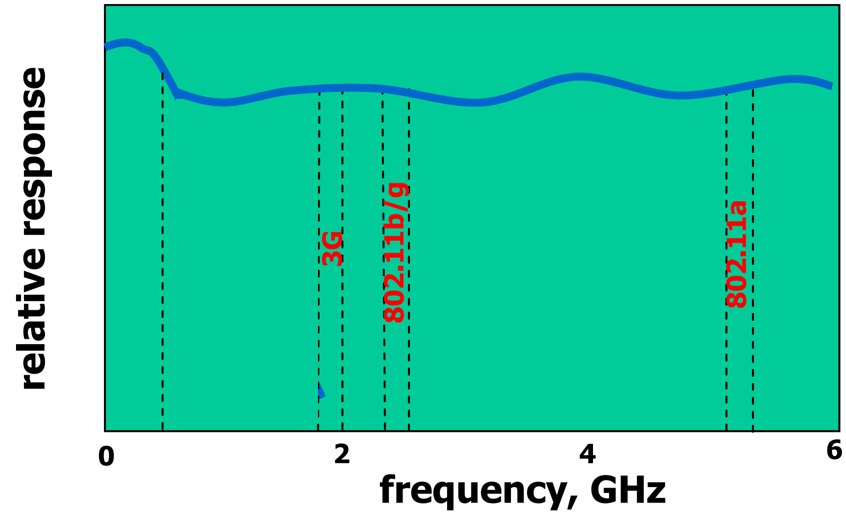

***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

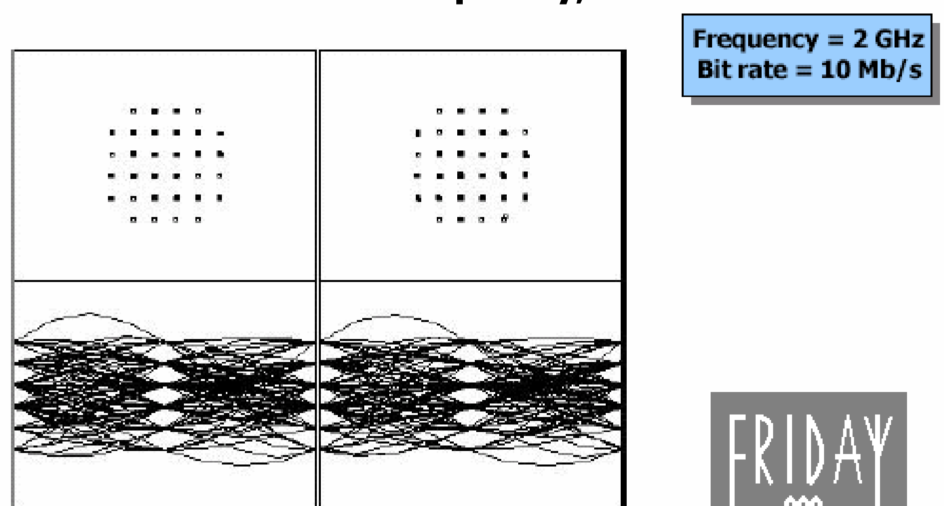
***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location
3. To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment
4. **To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services**
5. In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies

# Radio Distribution over MMF Fibre - Beyond the Bandwidth Limit!


Coaxial cable reference FP + 1km 50/125 + MD

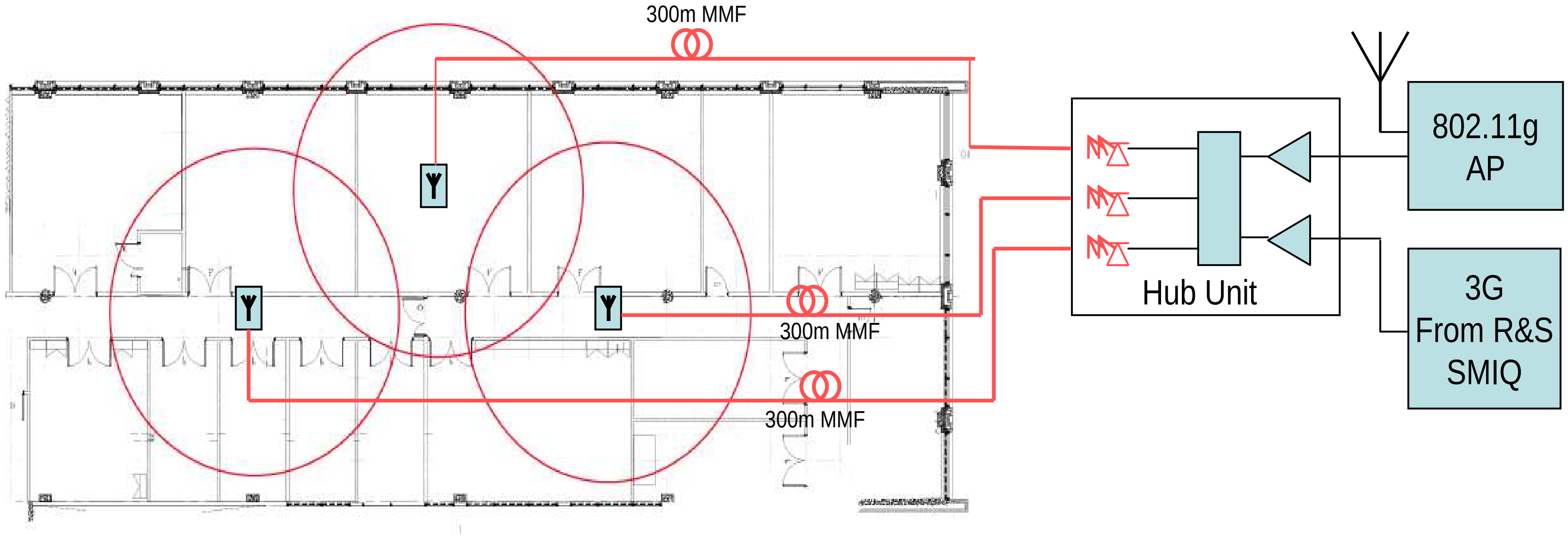
**April 2002: The FRIDAY project won the award for 'Most Forward Looking In-building Solution Provider' at this year's In-building Coverage European Summit in Barcelona.**

UNIVERSITY OF CAMBRIDGE

UCL

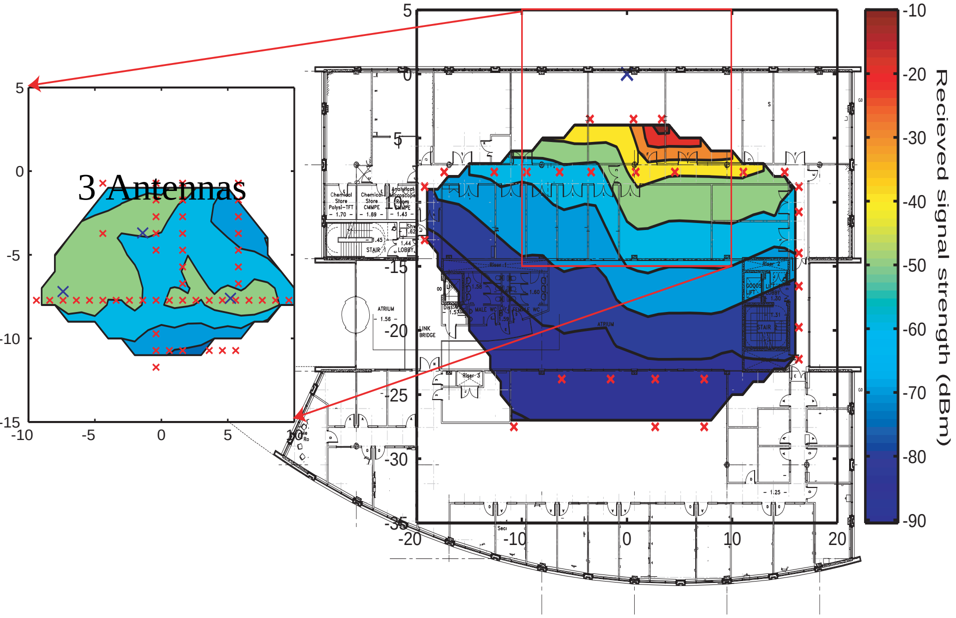
FRIDAY

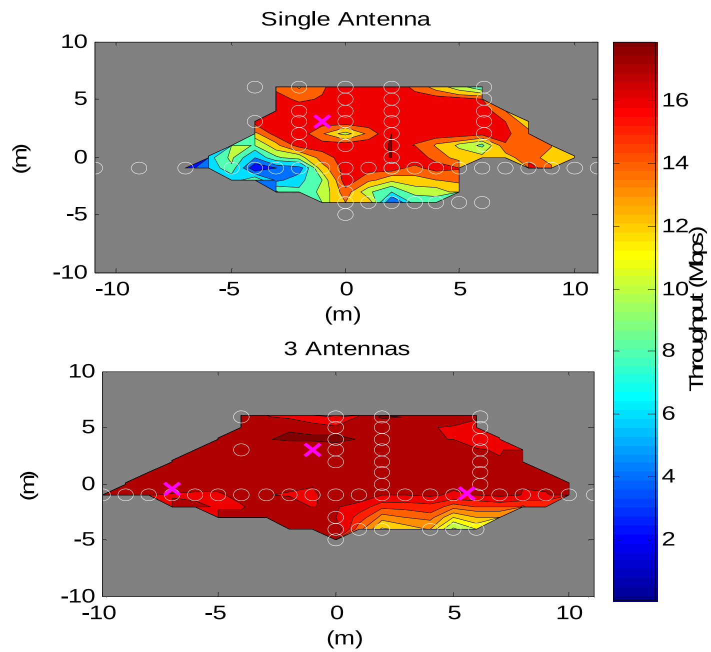

# Multi-Service Radio Distribution Network!

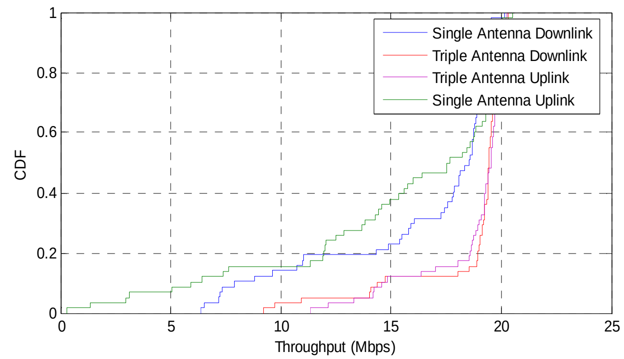



- Initial tests on three links in DAN with 2 services (WLan and 3G)
- Will rise to 8 links and up to 4 RF services in the short term


# Fibre DAN Performance

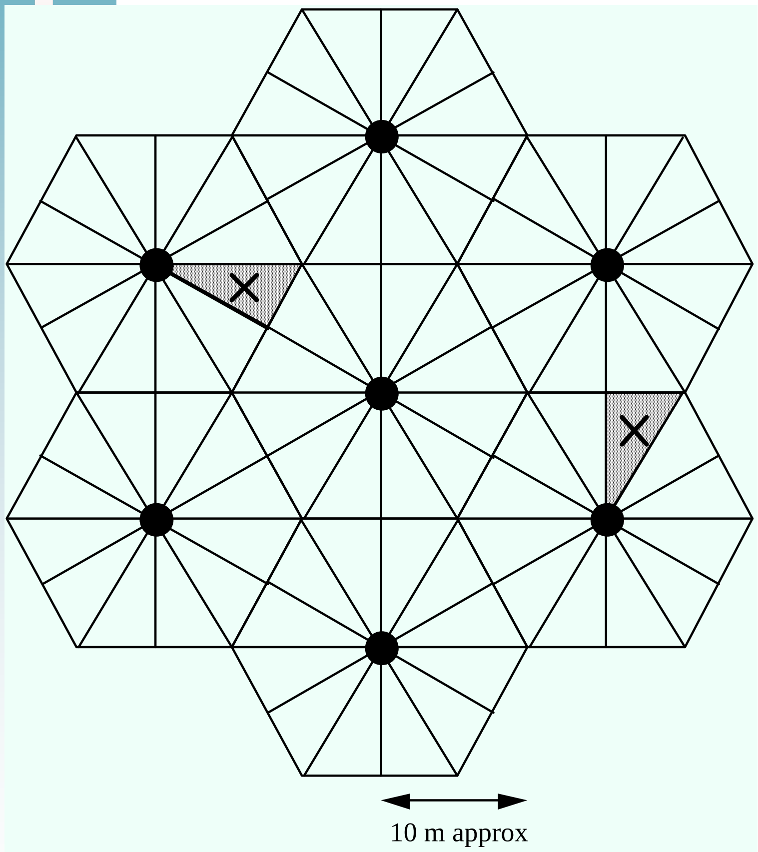



- DAN provides improved coverage at same Tx power levels
- Can overcome hidden node problem – but at reduced throughput

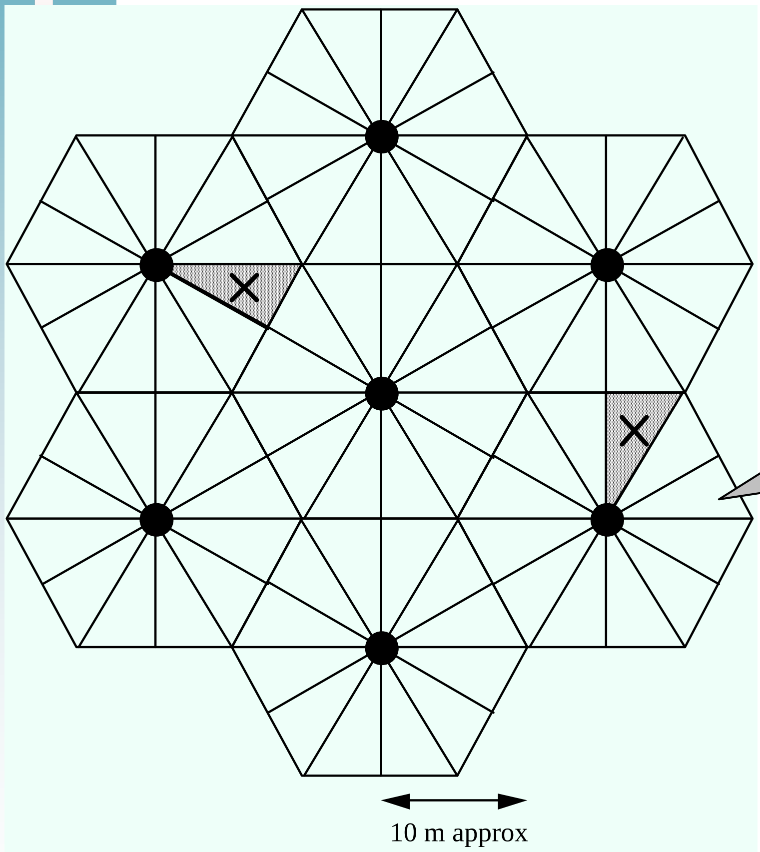

# Location Services via RFID and Video over ROF Infrastructure




- a cellular network of combined high resolution panoramic video cameras and RF-ID tag location units
- all passengers wear tags and movements monitored to 1 m accuracy in 1 s intervals
- user interface merges tag and video data - a powerful surveillance capability for safety and security purposes
- system automatically detects late-running passengers and helps them get to appropriate departure gate

UCL Optag


# Location Services via RFID and Video over ROF Infrastructure



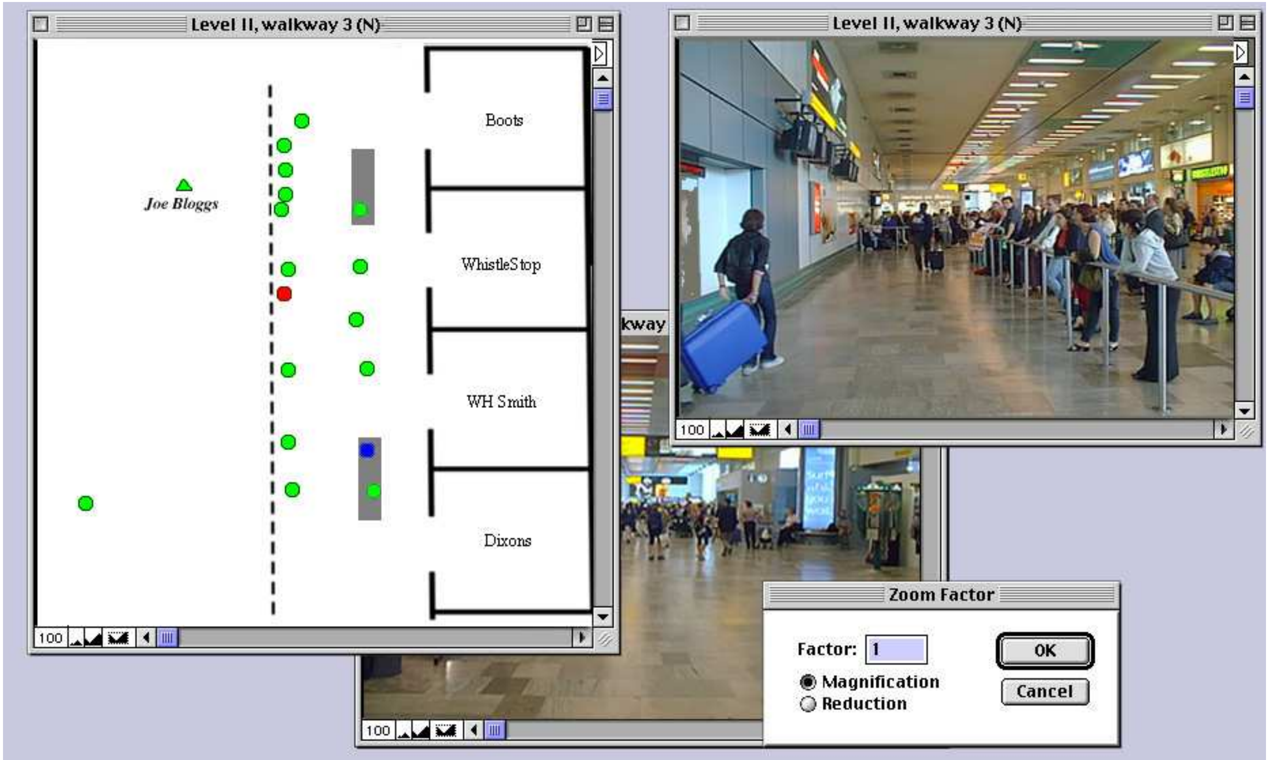

- a cellular network of combined high resolution panoramic video cameras a units
- all passe movemen accuracy
- user int vid
- urveillan and security p
- system automatically detects late-running passengers and helps them get to appropriate departure gate

"Airport security chiefs and efficiency geeks will be able to keep close tabs on airport passengers by tagging them with a high powered radio chip developed at the University of Central London."

Apocalyptic Church Website

UCL Optag


# A Typical User Interface




- separate map, live video and video playback windows
- green - no issues; blue - late-running passenger; red - discarded tag.
- options to track all tags and/or specific individuals (named triangles)
- auto-tracking facility to keep a specified tag within view at all times


# The Optag camera

## Colour panoramic image delivery

- 360° by 54° images supplied at 15 to 30 fps
- 9,600 x 1,600 pixels giving 0.03° per pixel
- geometrically calibrated, real-time seamless stitching
- in-camera processing, live panorama generation and
- person tracking

## Multiple live outputs

- allow multiple users access to live views;
- no need to mechanically pan and tilt the camera
- no camera synchronisation

UCL Optag

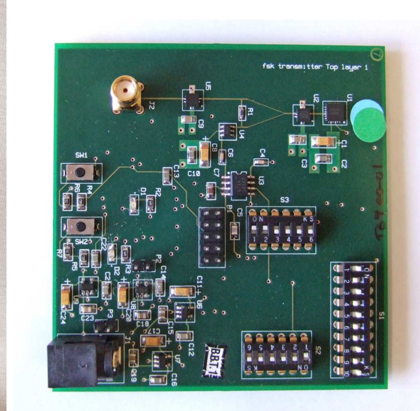
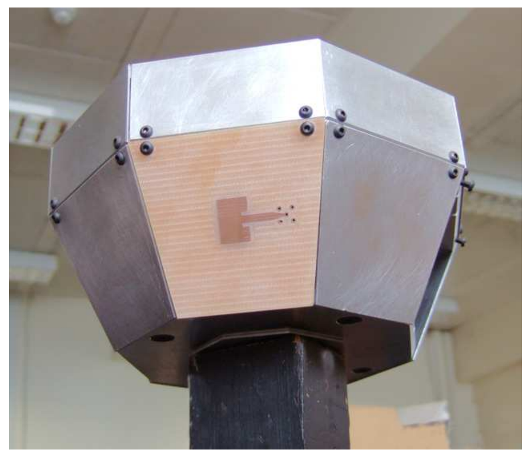
The INtelligent Airport

# Tag requirements

- tags must be compact, cheap, perhaps re-usable
- 10-20 m detection range (‘far-field’ tags)
- ability to identify 1000 tags per cell
- tag location capability, to ±1 m
- rapid update of tag identities and locations
- user interface to combine tag and camera data and allow their joint use, for instance, to track specific passengers

UCL

Optag

**Prototype Optag RF-ID tag, PCB and reader**

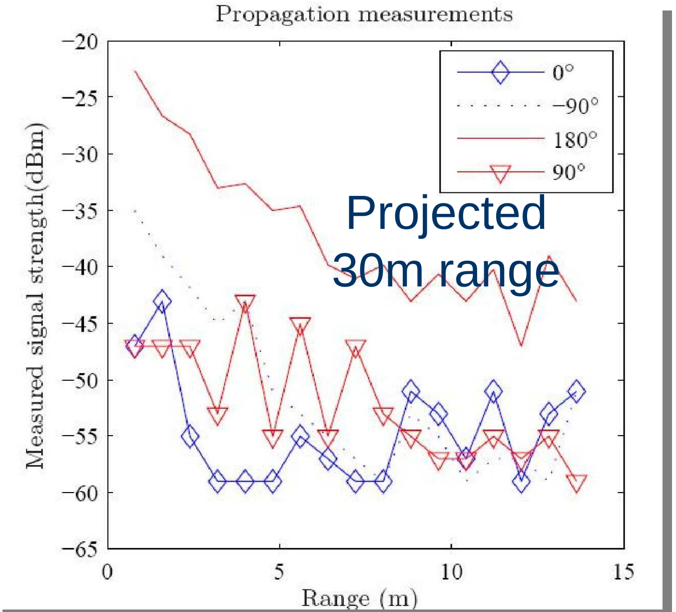
# Active RFID Airport Trial

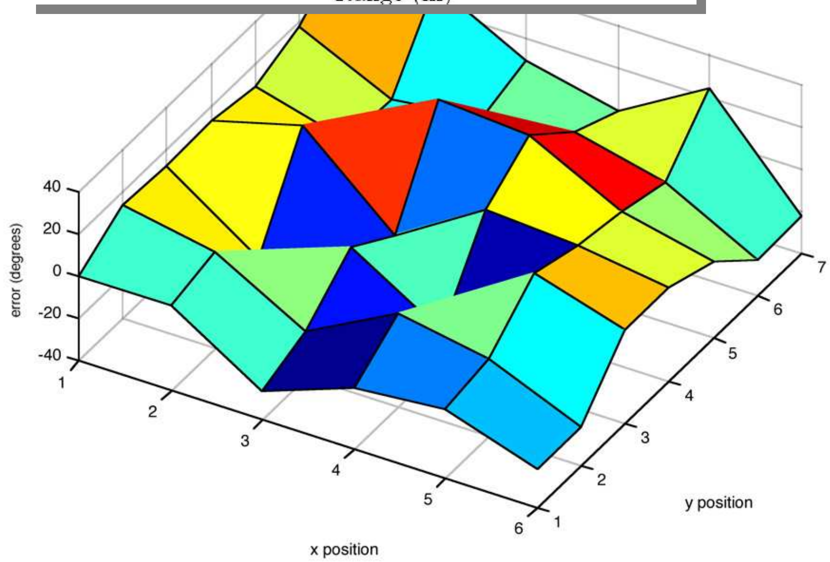


Debrecen airport, Hungary

UCL Optag


# Airport Trial – Results




Measured location error vs position

mean error: 0 degrees!

RMS error: 16 degrees

-corresponds to typical 1 m error over 0-10 m range

UCL Optag

# The INtelligent Airport


***Project Aims***: To develop a next generation advanced wired and wireless network for future *airport environments*

***Project Objectives***:

1. To study the feasibility of a single multi-service infrastructure to replace the many independently installed systems characteristic of current installations
2. To determine new system architectures which provide dynamic capacity allocation, wireless/wired interworking and device location
3. To determine new algorithms for addressing and routeing, able to operate seamlessly in a combined wired and wireless environment
4. To design a new form of wireless signal distribution network where multiservice antenna units cooperate, not only to provide communication, but also to provide identification and location services
5. **In collaboration with our industrial partners, to define and build small proof of principle demonstrators using the proposed architectures and technologies**


# Intelligent Gate Demonstrator

UNIVERSITY OF CAMBRIDGE

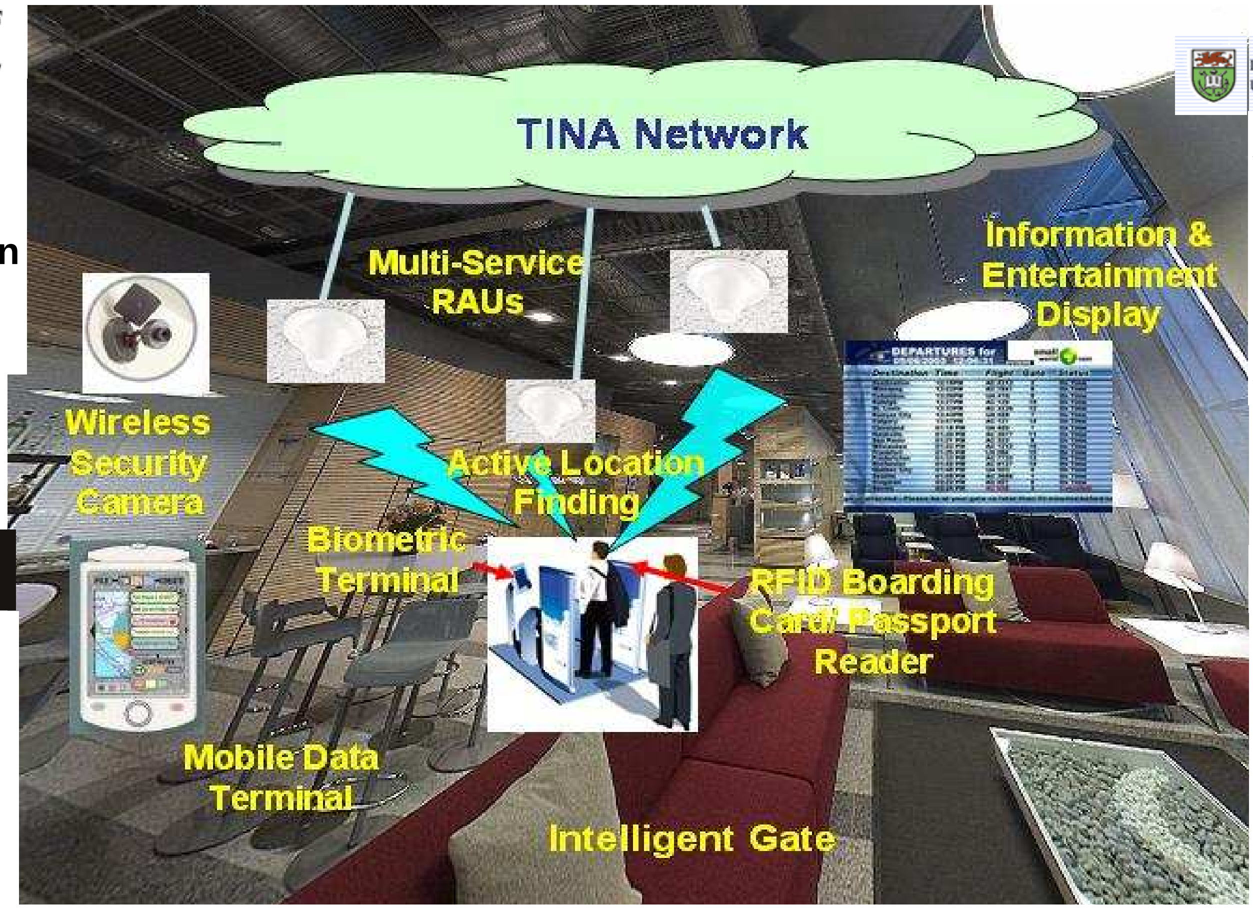
*Computer Lab*

**Architectures**
**Protocols**
**System simulation**
**Demo Specification**

UCL

**Demo Spec.**

**Active RFID systems**
**Multi-service RoF Network construction**




PRIFYSGOL CYMRU ABERTAWE
UNIVERSITY OF WALES SWANSEA

**Architectures**
**Protocols**
**Passive RFID systems**
**Demo Specification**

UNIVERSITY OF CAMBRIDGE

*Engineering*

**Demo Spec.**
**RoF Links**
**System design**
**Network construction**


# Thank You!