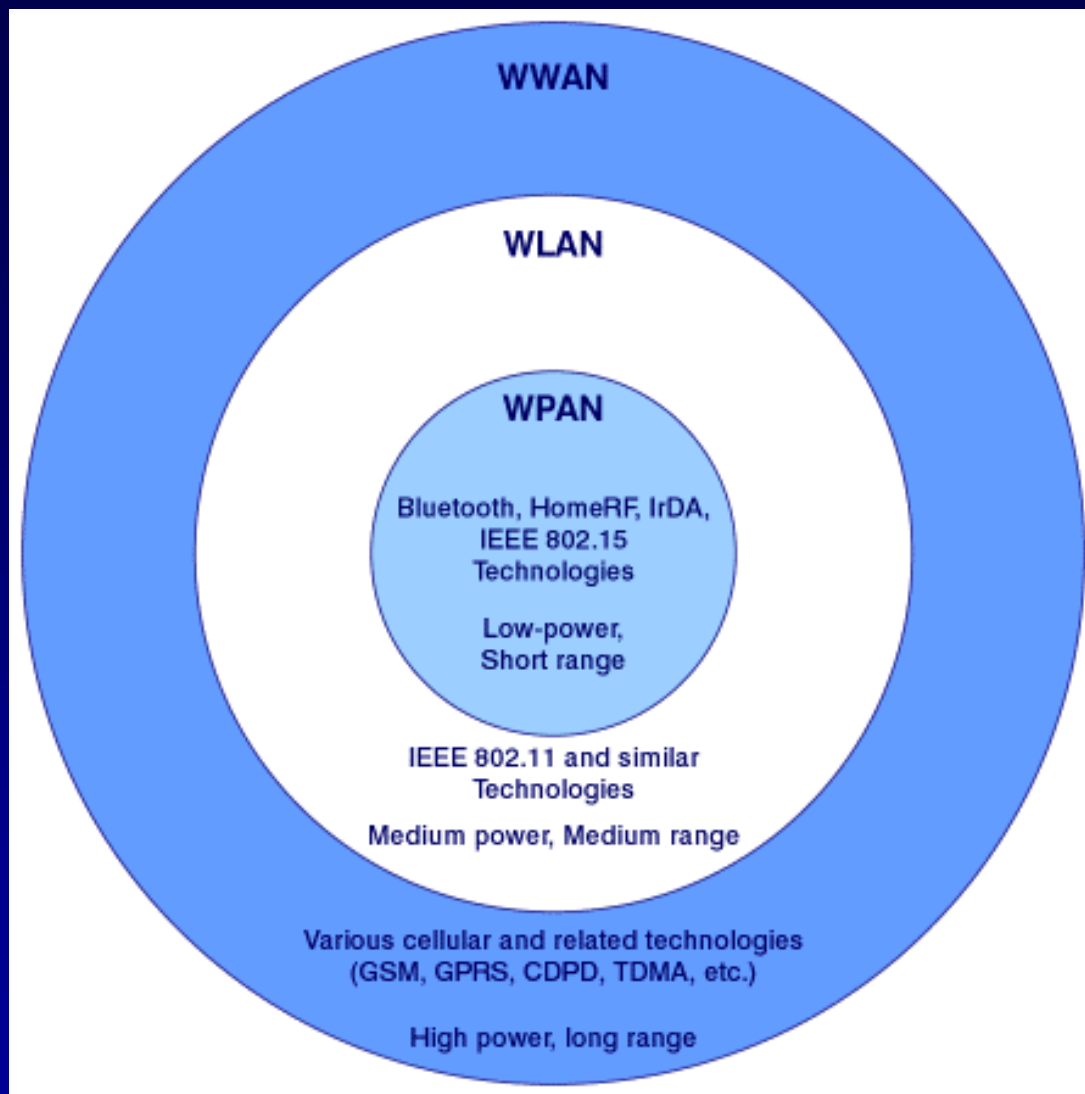# *Wireless Access Networks: Technology & Research Challenges*

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National University of Singapore, Singapore

&

Research Staff Member

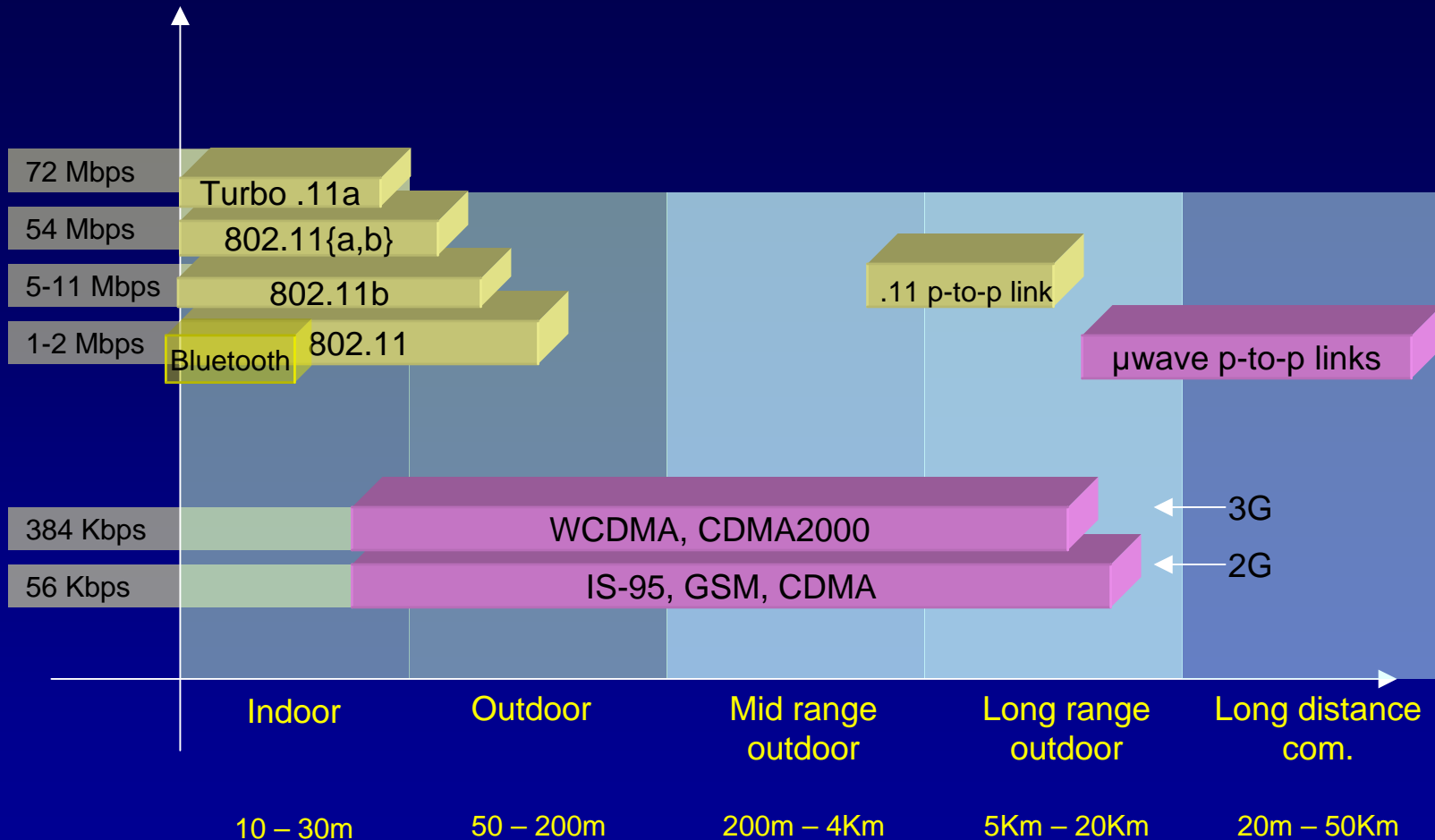IBM India Research Laboratory

New Delhi, India

Overview

- **Existing and Emerging Wireless Technologies**

- **Wireless Access Networks: Status and Trends**
  - ‣ WLANs (Wi-Fi)
  - ‣ WMANs (Wi-Max)

- **Vision for the Future**
  - ‣ Key Technical Challenges
  - ‣ Future Environment

- **Concluding Remarks**

The Wireless Space: From WPANs to WWANs

WWAN

WLAN

WPAN

Bluetooth, HomeRF, IrDA,
IEEE 802.15
Technologies

Low-power,
Short range

IEEE 802.11 and similar
Technologies

Medium power, Medium range

Various cellular and related technologies
(GSM, GPRS, CDPD, TDMA, etc.)

High power, long range

Wireless Technology : Current Landscape

72 Mbps — Turbo .11a

54 Mbps — 802.11{a,b}

5-11 Mbps — 802.11b

1-2 Mbps — Bluetooth 802.11

.11 p-to-p link

µwave p-to-p links

384 Kbps — WCDMA, CDMA2000 — 3G

56 Kbps — IS-95, GSM, CDMA — 2G

Indoor	Outdoor	Mid range outdoor	Long range outdoor	Long distance com.
10 – 30m	50 – 200m	200m – 4Km	5Km – 20Km	20m – 50Km

Existing and Emerging Wireless Technologies

Network	Standard	Radio Basic Rate	Frequency Band	Mobility
WLAN	IEEE 802.11b IEEE 802.11a IEEE 802.11g	1, 2, 5.5, 11 Mbps Up to 54 Mbps Up to 54 Mbps	ISM 2.4 GHz ISM/UNI 5 GHz ISM 2.4 GHz	Low Low Low
Bluetooth	IEEE 802.15.1	1 Mbps	ISM 2.4 GHz	Low
WMAN	IEEE 802.16 IEEE 802.16a	134 Mbps 70 Mbps	10 - 66 GHz 2 - 11 GHz	N/A N/A
2G	GSM GPRS EDGE	9.6/57.6 Kbps 115 Kbps 384 Kbps	900/1.8K/1.9K MHz	High High High
3G	UMTS/WCDMA	Up to 2 Mbps	1900 – 2025 MHz	High
UWB	IEEE 802.15.3a or de facto?	Potentially upto 400 Mbps	3.1 – 10.6 GHz (FCC)	N/A
Sensors, UbiComp	IEEE 802.15.4 and proprietary systems	5 – 200 Kbps	433, 866, 916 MHz 2.4 GHz (ISM)	N/A or low
Next-gen WLANs		Upto 1 Gbps (indoor), 150-250 Mbps (outdoor)	-	Low

Networks of the Future

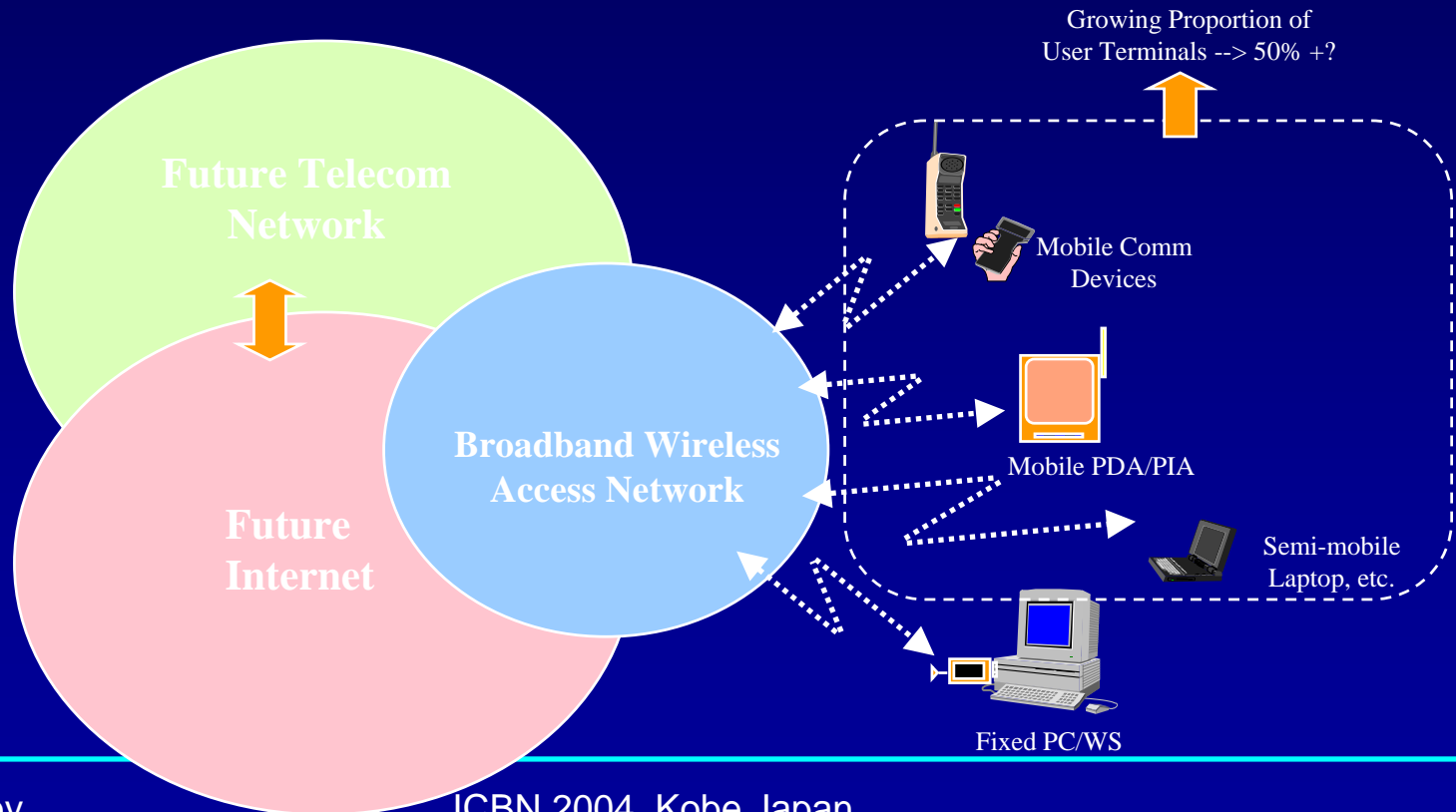*Ad Hoc Peer-to- Peer Routing Technology (meshnetworks)*
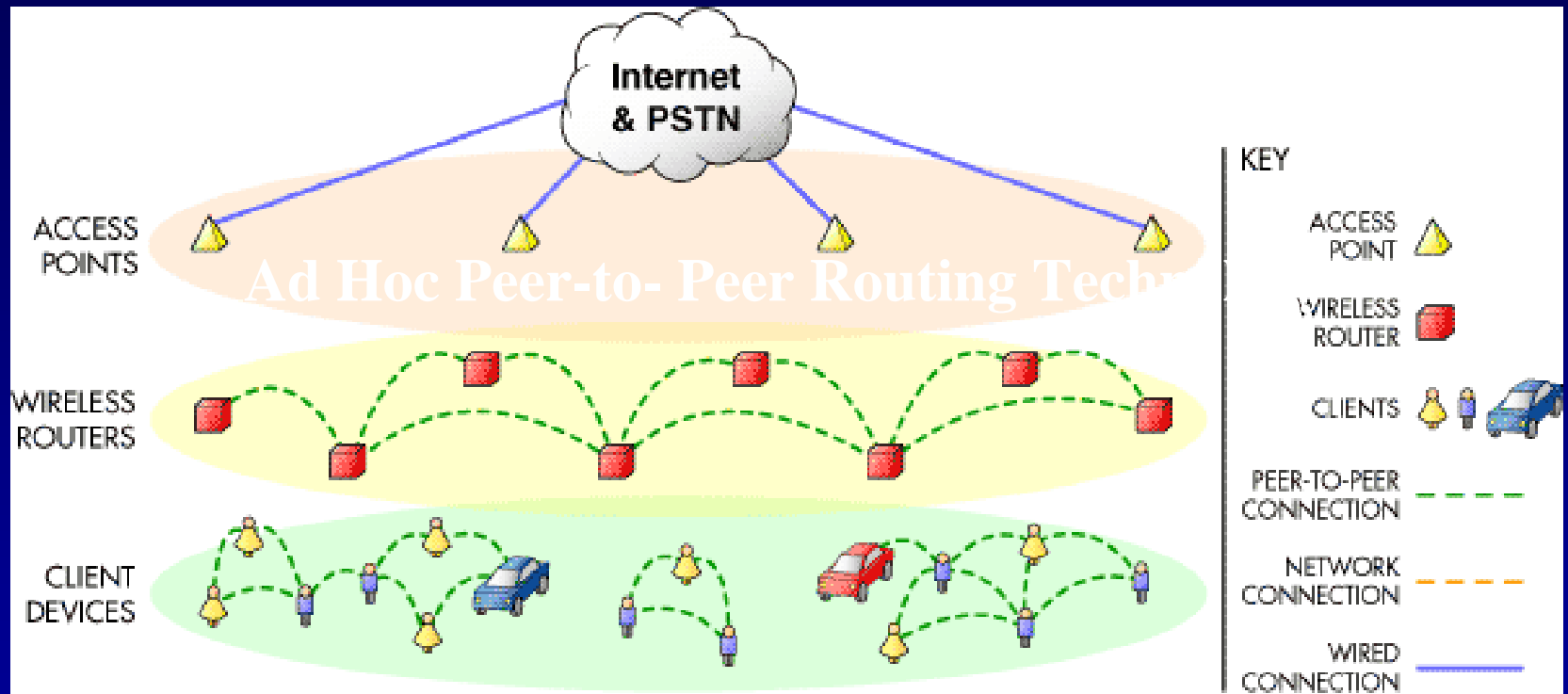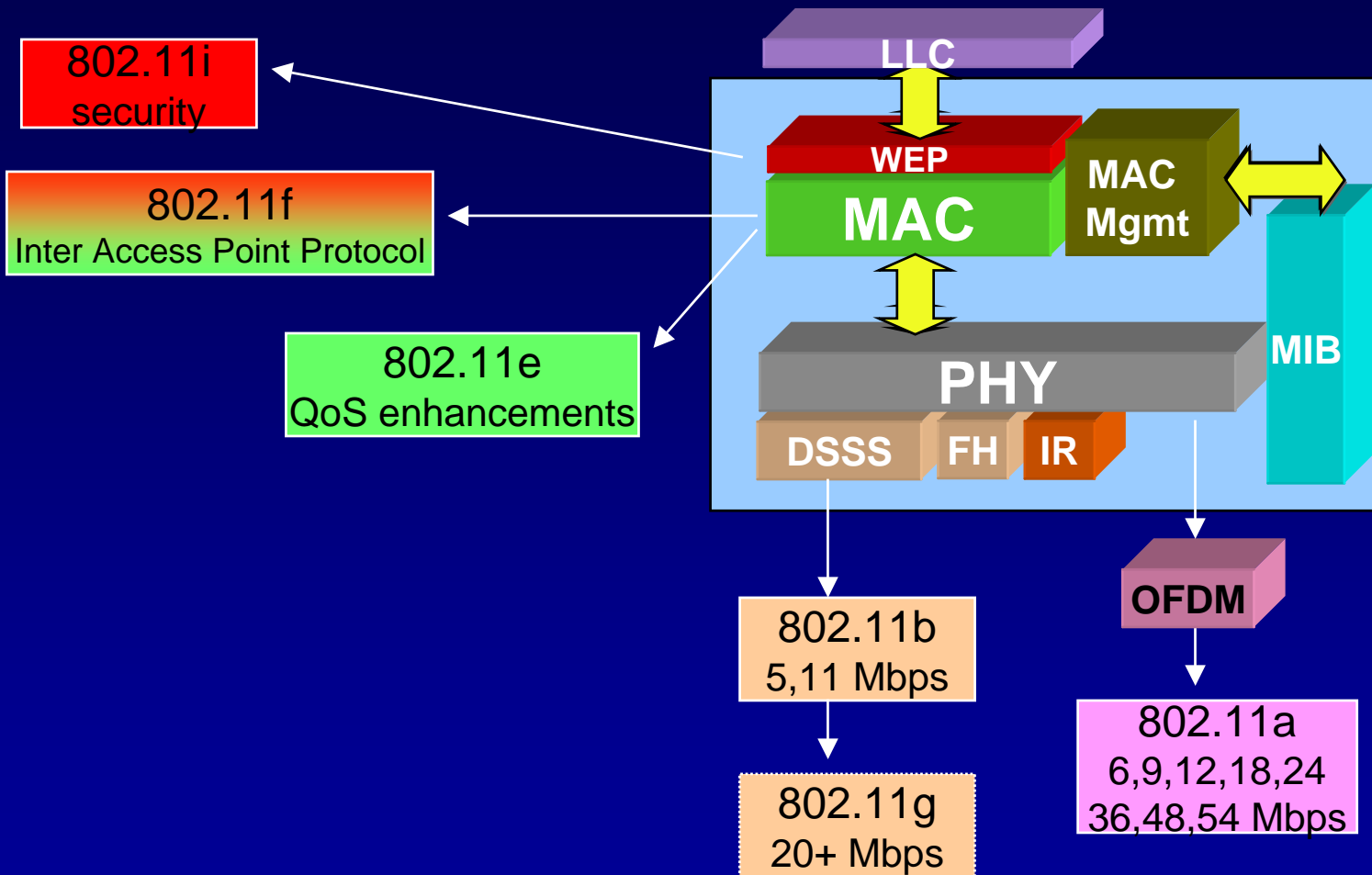
Networks of the Future

Broadband Wireless Vision

■ Broadband wireless networks a key enabling technology for mobile multimedia services of the future……. (while also facilitating rapid/flexible deployment of high-speed access to fixed computing devices in the near-term)

Growing Proportion of User Terminals --> 50% +?

Future Telecom Network

Future Internet

Broadband Wireless Access Network

Mobile Comm Devices

Mobile PDA/PIA

Semi-mobile Laptop, etc.

Fixed PC/WS

IEEE 802.11
Status and Trends

802.11 Current Status

802.11i
security

802.11f
Inter Access Point Protocol

802.11e
QoS enhancements

LLC

WEP

MAC

MAC Mgmt

PHY

MIB

DSSS   FH   IR

OFDM

802.11b
5,11 Mbps

802.11g
20+ Mbps

802.11a
6,9,12,18,24
36,48,54 Mbps

IEEE 802.11 Specifications

	802.11b	802.11g	802.11a
Max. Speed	11 Mbps	54 Mbps	54 Mbps
Modulation	CCK	OFDM & CCK	OFDM
Frequencies	2.4 – 2.497 GHz	2.4 – 2.497 GHz	5 GHz band
Approval	July 1999	June 2003	July 1999

Other Task Groups

- **802.11d**
  - ▸ The group is focusing on extending the technology to countries that are not covered by the IEEE
- **802.11e**
  - ▸ The group is focusing on improving multi-media transmission quality of service
- **802.11f**
  - ▸ The group is focusing on enhancing roaming between APs and interoperability between vendors
- **802.11h**
  - ▸ The group is addressing concerns on the frequency selection and power control mechanisms on the 5 GHz band in some European countries
- **802.11i**
  - ▸ The group is focusing on enhancing wireless LAN security and authentication for 802.11 that include incorporating Remote Access Dialing User Service (RADIUS), Kerberos and the network port authentication (IEEE 802.1X)
  - ▸ 802.1X has already been implemented by some AP vendors
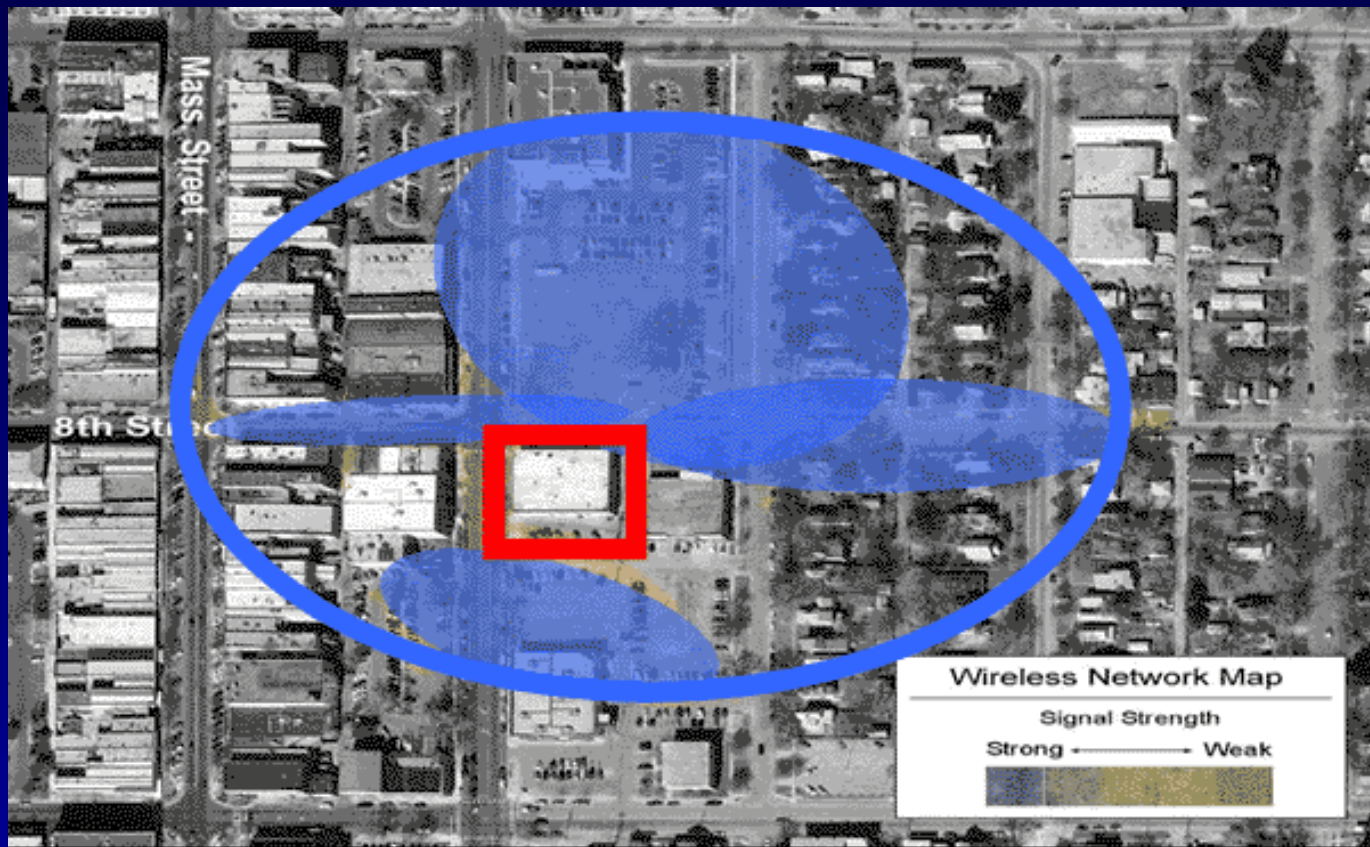
WLAN Security

Wireless LAN Security

Figure 1: This image represents the signal emitted from a single wireless access point located in downtown Lawrence, KS

Threats to Wireless LAN Security

- **Internal Vulnerabilities**
  - ▶ Rogue WLANs
  - ▶ Insecure Network Configurations
  - ▶ Accidental Associations
- **External Threats**
  - ▶ Eavesdropping and Espionage
  - ▶ Identity Theft
    - • Service Set Identifiers (SSIDs)
    - • MAC Addresses
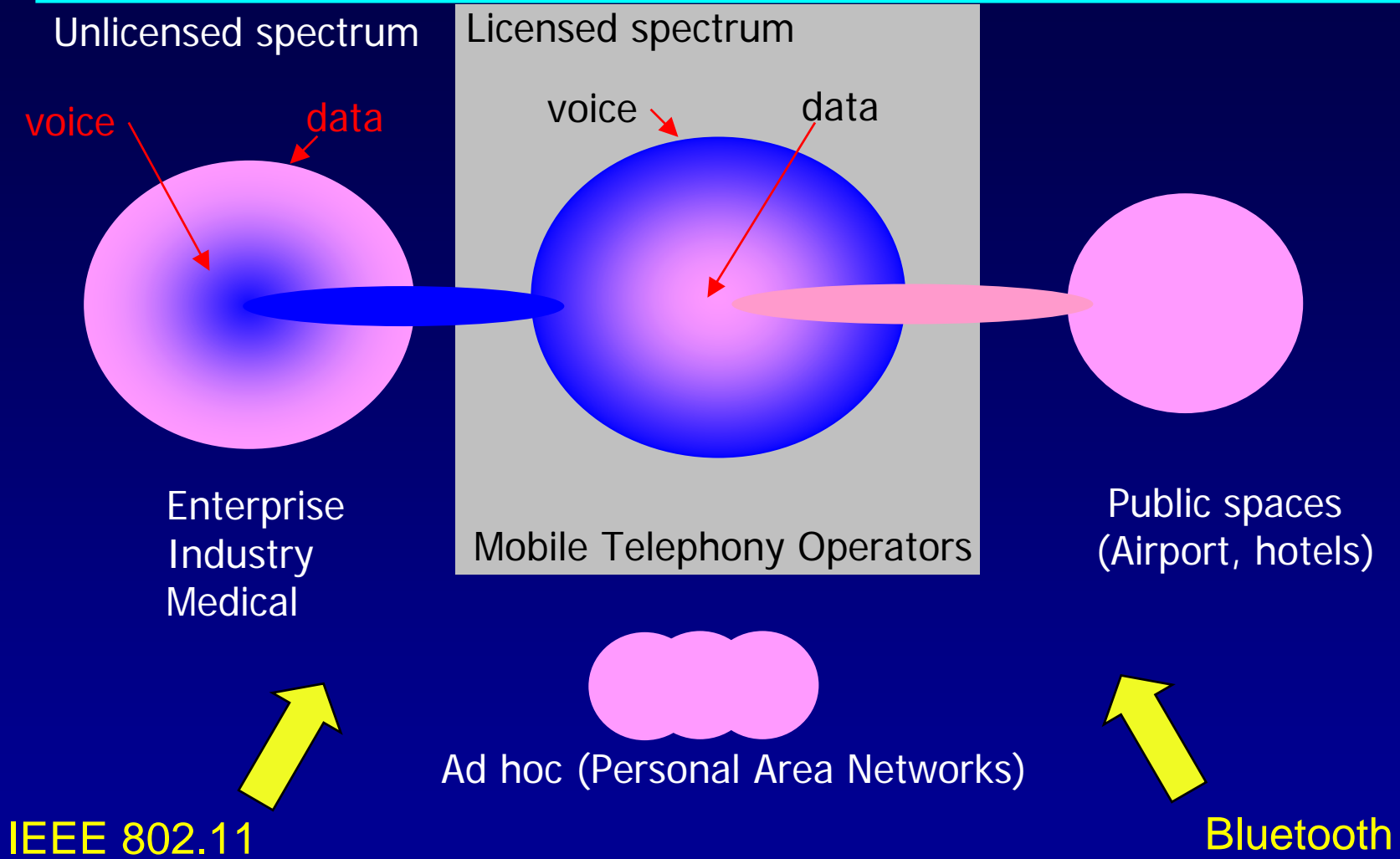 - ▶ Evolving Attacks

Hacker's Wireless LAN Toolbox

- Many hardware and freeware tools available on the Internet
- Available Freeware Tools
  - ▸ NetStumbler
  - ▸ Kismet
  - ▸ Wellenreiter
  - ▸ THC-RUT
  - ▸ Ethereal
  - ▸ WEPCrack
  - ▸ AirSnort
  - ▸ HostAP

Available Freeware Tools

- What do these tools do?
  - ▶ Wireless sniffers and monitors
  - ▶ Passively monitor wireless traffic and sorts data to identify
    - SSIDs
    - MAC addresses
    - Channels
    - Connection speeds
  - ▶ Use brute force to identify low traffic access points
  - ▶ Interactively browse the capture data
  - ▶ Crack 802.11 WEP encryption keys using the latest discovered weakness of RC4 key scheduling
  - ▶ Computing the encryption key when enough packets have been gathered
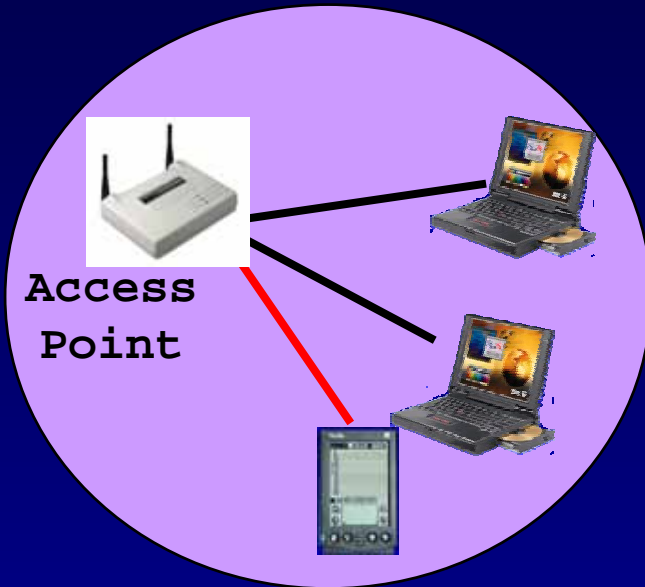 - ▶ …

WLAN versus Bluetooth

WLAN versus Bluetooth

Unlicensed spectrum

Licensed spectrum

voice   data

voice   data

Enterprise
Industry
Medical

Mobile Telephony Operators

Public spaces
(Airport, hotels)

Ad hoc (Personal Area Networks)

IEEE 802.11

Bluetooth

Who will be the winner ?

Two options: 802.11 and Bluetooth

802.11

Bluetooth

New developments are blurring the distinction

- 802.11b for PDAs
- Bluetooth for LAN access

`Access Point`

`Cordless headset`

Designed for wired Ethernet replacement
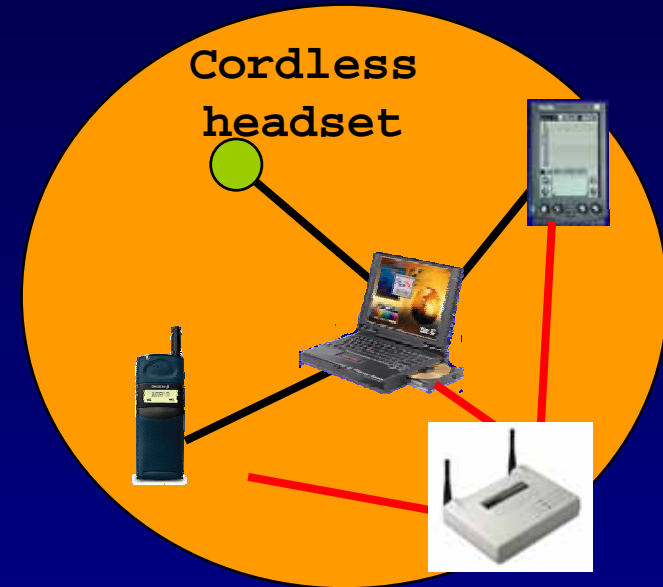
Designed for cable replacement

802.11 Market Evolution

802.11

Industry Verticals	Campus Networking	Enterprise	Public hotspots Mobile Operators	Broadband access to home
Warehouses Factory floors Medical Remote data entry; business process efficiency improvement	Mobile user population without any office space	Freedom from wires for laptop users; productivity enhancement	Revenue generation opportunity; low cost alternative to GPRS	Untested proposition; attempts are on-going

The Popularity of Wi-Fi

- Year 2003
  - ▸ In-Stat/MDR
  - ▸ 22.7 million network interface cards and access points rolled out
- Wi-Fi hardware business
  - ▸ Billion dollar sector with 2003 revenues of $ 1.7 billion

Source

Network World Fusion (www.nwfusion.com)

Trends in Wi-Fi

- Convergence of voice and data over a Wi-Fi infrastructure

- Combined IP phone/base station system
  - Roaming
  - Handoff
  - Device authentication from one base station to another as a user moves throughout an office from one access point to another

- Future
  - Wi-Fi / IP phones
  - Sophisticated location-based services

IEEE 802.16 Fixed Broadband Wireless Access (Wi-Max)

Fixed Broadband Wireless Access
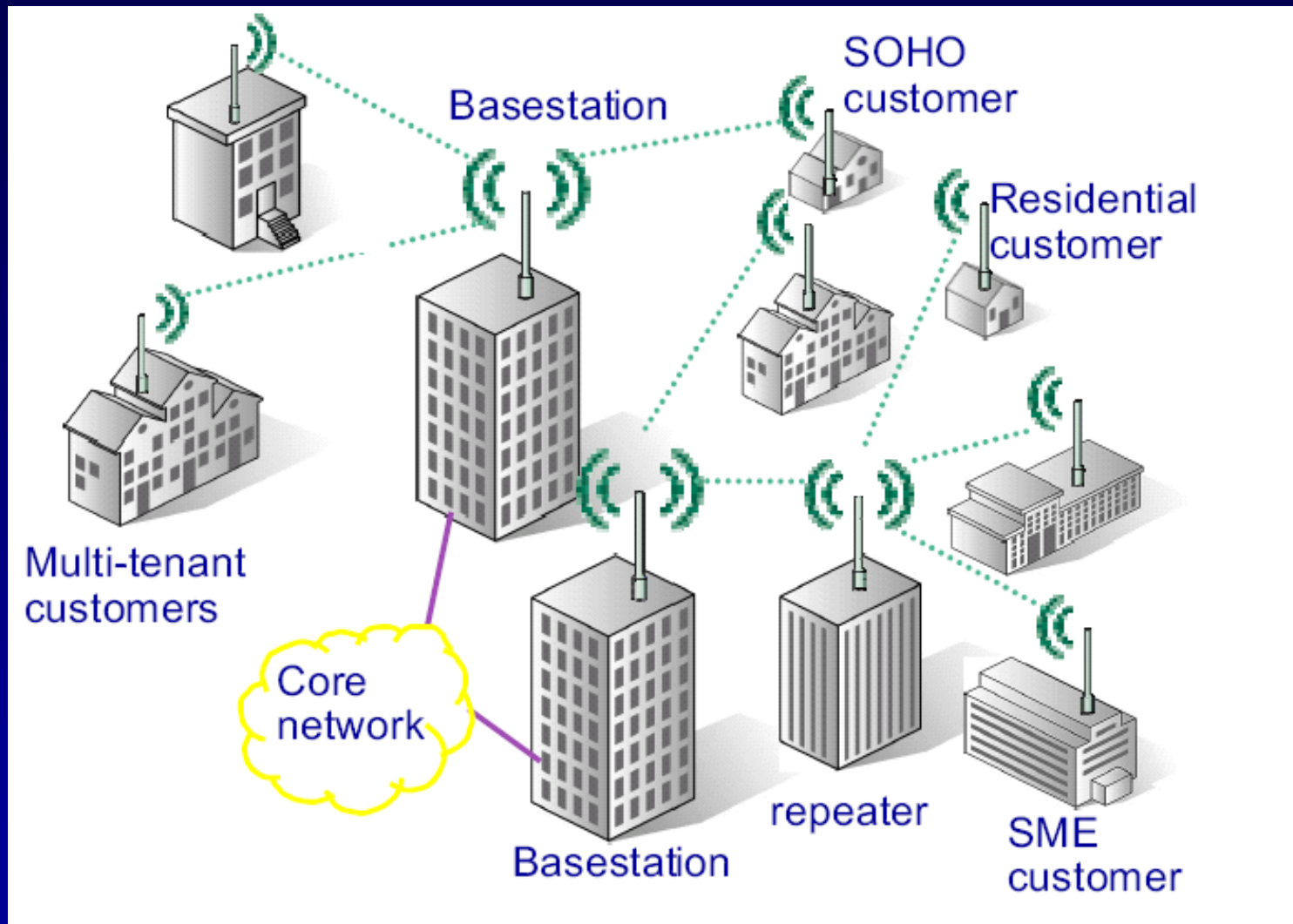
IEEE 802.16 Broadband Wireless Access: Wi-Max

- Worldwide Interoperability for Microwave Access
- WAN technology that can beam broadband signals upto 30 miles from a cell tower
- IEEE 802.16
  - ▸ Being touted as the last-mile alternative to DSL and cable modem
  - ▸ Future
    - Basis for ubiquitous, continuous mobile wireless connectivity
  - ▸ Bandwidth
    - From a single base station, an antenna can transmit as much as 75 Mbps of bandwidth for 2 to 3 miles

IEEE 802.16 Broadband Wireless Access

- **IEEE 802.16**
  - ▸ Frequencies from 10 to 66 GHz
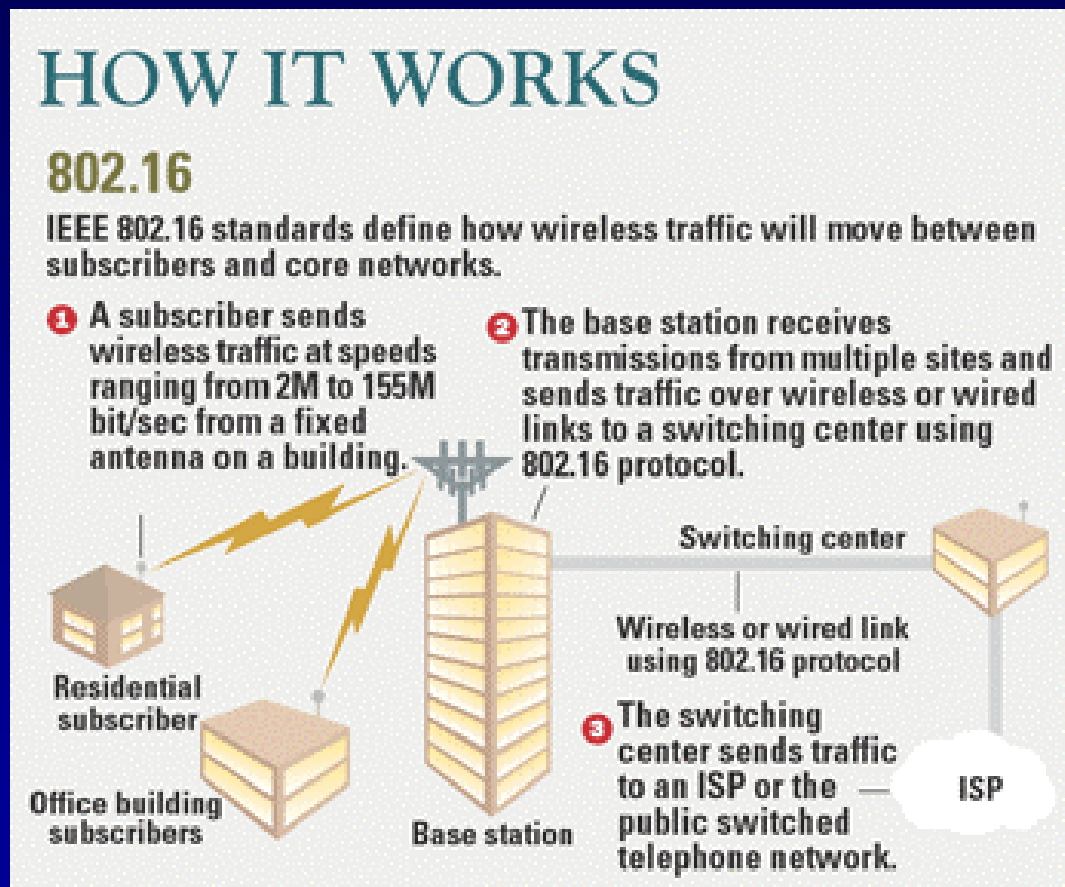 - ▸ Significant deployment challenges
- **IEEE 802.16a**
  - ▸ Frequencies from 2 to 11 GHz band
  - ▸ Includes both licensed and license exempt spectra

WMAN versus WLAN

- Comparison to a Wireless LAN
  - Multimedia QoS, not only contention based
  - Many more users
  - Much higher data rates
  - Much longer distances

The IEEE 802.16 Working Group

- **The IEEE 802.16 Working Group on Broadband Wireless Access Standards**

HOW IT WORKS

802.16

IEEE 802.16 standards define how wireless traffic will move between subscribers and core networks.

1 A subscriber sends wireless traffic at speeds ranging from 2M to 155M bit/sec from a fixed antenna on a building.

2 The base station receives transmissions from multiple sites and sends traffic over wireless or wired links to a switching center using 802.16 protocol.

Switching center

Wireless or wired link using 802.16 protocol

3 The switching center sends traffic to an ISP or the public switched telephone network.

ISP

Residential subscriber

Office building subscribers

Base station

Market

- Broadband wireless equipment sales should surpass $ 1.5 billion by 2008 mostly because of Wi-Max
  - ABI Research Report (NW Fusion, March, 2004)

Wi-Max: Future Areas

- ## IEEE 802.16e

  - ▸ Will allow seamless handoffs between base stations

  - ▸ Providing true mobile broadband connectivity

- ## IEEE 802.16d

  - ▸ The technology embedded in PCMCIA cards

  - ▸ Customers will be able to access Wi-Max directly from their laptops

PHY Considerations

- Line of Sight (because of 10-66 GHz)
  - Negligible multi-path => Large channels
- Broadband Channels
  - Wide channels (20, 25 or 28 MHz)
  - High capacity – Downlink AND Uplink
- Multiple Access
  - TDM/TDMA
  - High rate burst modems
- Adaptive burst profiles on Uplink and Downlink
- Multiple duplex schemes
  - TDD
  - FDD (including Burst FDD)
    - Support for half-duplex terminals
- <u>Both TDD and FDD alternatives support adaptive burst profiles</u>
  - *<u>Modulation and Coding options may be dynamically assigned on a burst-by-burst basis</u>*

Medium Access Control

- To support variety of services
  - IEEE 802.16 MAC must accommodate both continuous and bursty traffic
- 802.16 MAC must also support a variety of backhaul requirements
  - ATM
  - Packet-based protocols
- Downlink
  - Data to SSs are multiplexed in TDM fashion
- Uplink
  - Shared between SSs in TDMA fashion
- MAC is connection-oriented
- Details of scheduling and reservation management are left unstandardized
  - Provide an important mechanism for vendors to differentiate their equipment

IEEE 802.20 Mission and Project Scope

- **IEEE 802.20**
  - ▸ The Mobile Broadband Wireless Access (MBWA)
- **Mission**
  - ▸ The mission of IEEE 802.20 is to develop the specification for an efficient packet based air interface that is optimized for the transport of IP based services
  - ▸ The goal is to enable worldwide deployment of affordable, ubiquitous, always-on and interoperable multi-vendor mobile broadband wireless access networks that meet the needs of business and residential end user markets
- **MBWA Scope**
  - ▸ Specification of physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems
  - ▸ Operating in licensed bands below 3.5 GHz
  - ▸ Optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps
  - ▸ It supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems.

FUTURE CHALLENGES

Challenges in WLANs

- QoS in WLANs
- Co-existence
  - 802.11b
  - 802.11g
  - 802.11a

802.11i
security

802.11f
Inter Access Point Protocol

802.11e
QoS enhancements

LLC

WEP

MAC

MAC Mgmt

PHY

MIB

DSSS   FH   IR

OFDM

802.11b
5,11 Mbps

802.11g
20+ Mbps

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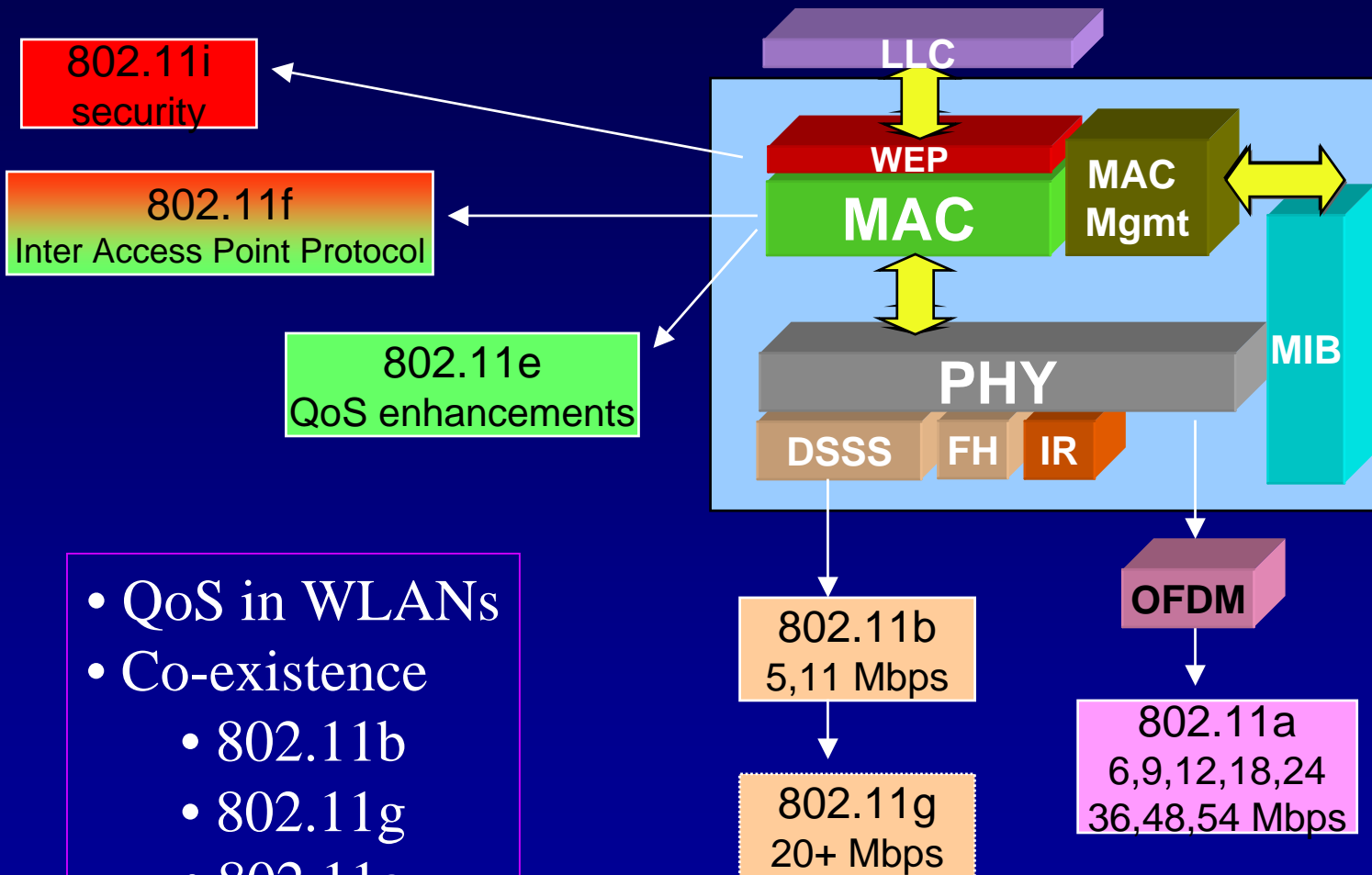
Coverage versus Performance Tradeoff

- **IEEE 802.11b/802.11g**
  - ▸ 802.11g is backward compatible with 802.11b
  - ▸ Both sharing the 2.4 GHz band – crowded band
  - ▸ Three non-overlapping channels
    - ● When interference is encountered on one channel, there isn't much room to move
  - ▸ Performance Degradation
    - ● To handle slower clients, 802.11g networks decrease their data rates in the presence of 802.11b clients
    - ● Limits AP throughput to the 11 Mbps of 802.11b
  - ▸ Greater range of 802.11b/802.11g translates into fewer access points for a given coverage area
- **IEEE 802.11a**
  - ▸ High throughput
  - ▸ High cost
  - ▸ Will the capacity gains of 802.11a justify the additional cost?
- **Solution**
  - ▸ Multi-mode capabilities rapidly becoming the norm

# *Deployment Issues in Wireless LANs*

- How many Access Points to deploy?
- Optimum placement of the APs
  - ‣ Complex problem
    - Attenuation effects
    - Multi-path distortion
    - Structural issues
    - Interference from other sources in the same band
    - Number of users (estimate)
    - What kind of traffic?

IEEE 802.11 EDCF: A QoS Solution for WLAN

■ Multiple FIFO queues in the MAC
  ▸ Priority Queuing
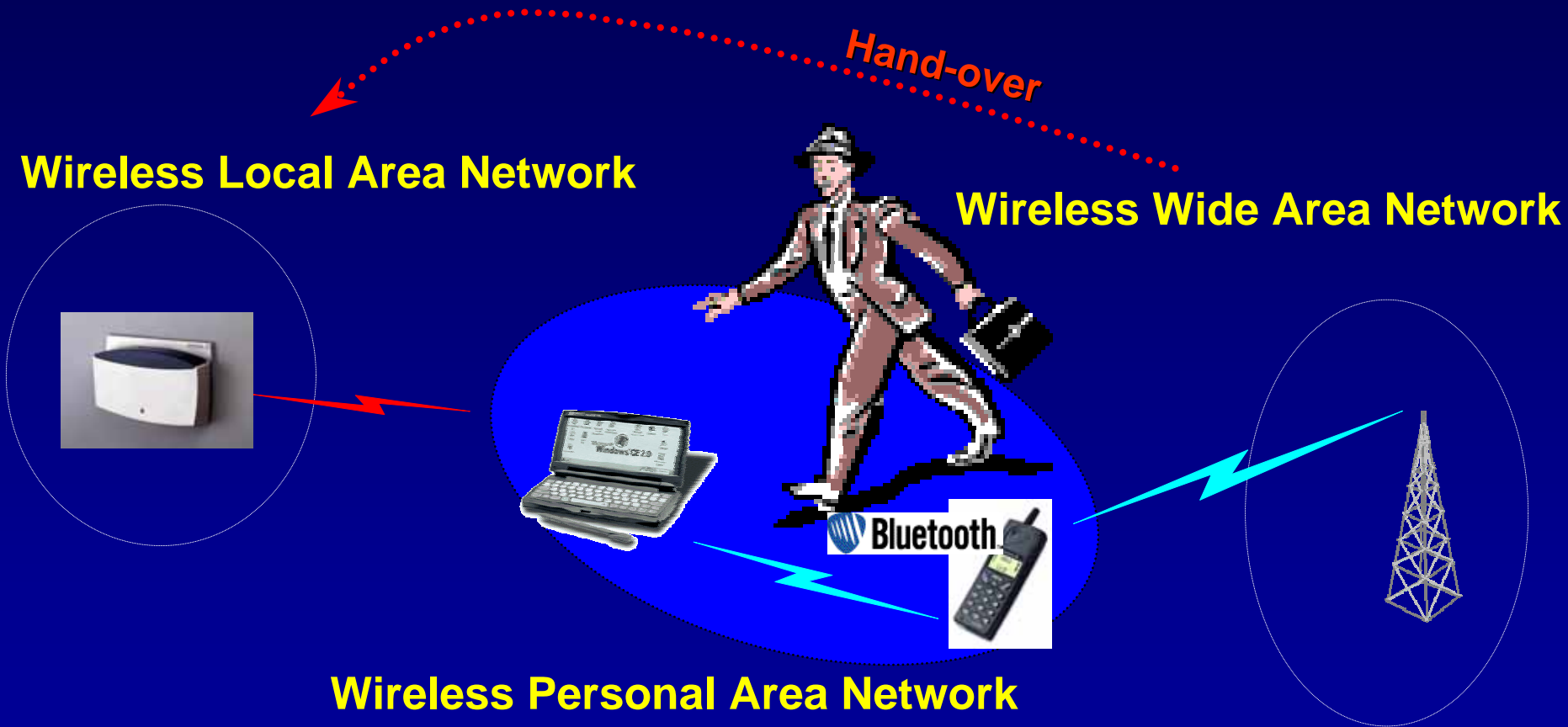■ Every queue is an independent contention entity with its own contention parameters
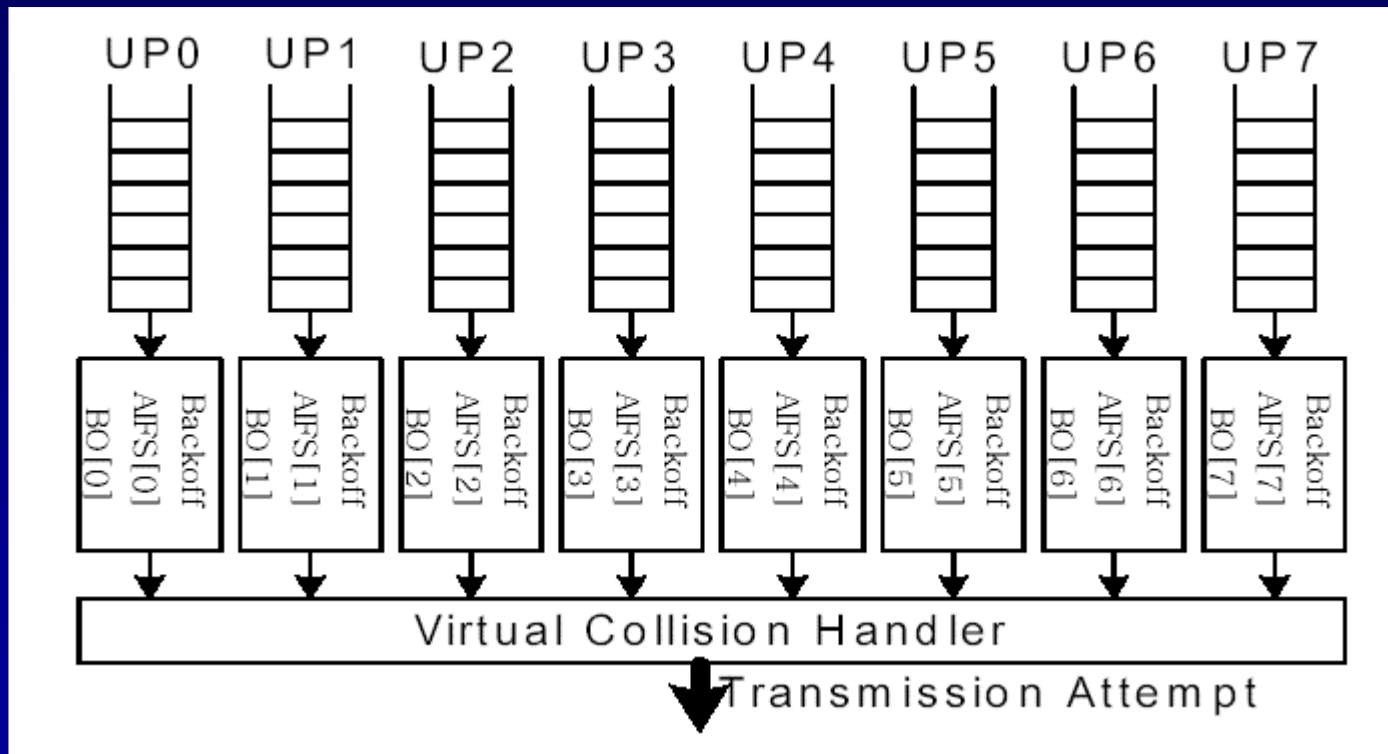
Challenges in Wi-Max
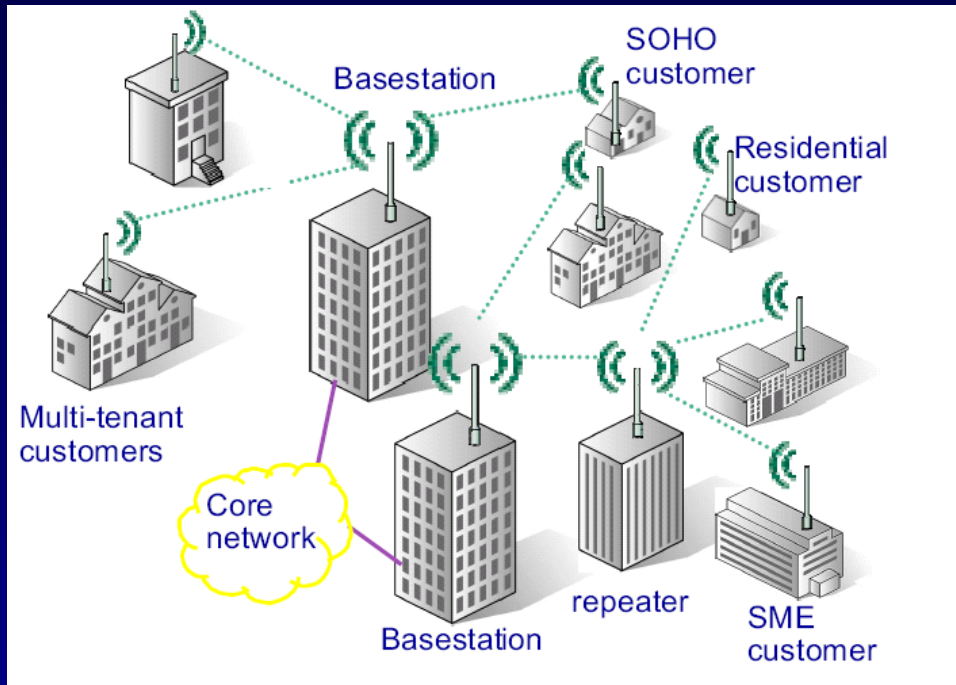
- ■ Performance and Capacity

  - ‣ Will it truly be a cable/DSL replacement technology ?

- ■ QoS
  - ‣ Scheduling

- ■ Seamless handoffs
  - ‣ Enabled by IEEE 802.16e

Wireless Inter-working Technologies

- Interoperability
- Handovers

Hand-over

Wireless Local Area Network

Wireless Wide Area Network

Bluetooth

Wireless Personal Area Network

Integration of Wi-Fi and Cellular Technologies

- **Vision**
  - ‣ A single handset that can seamlessly move from a Wi-Fi network to a cellular network while supporting a non-interrupted voice call
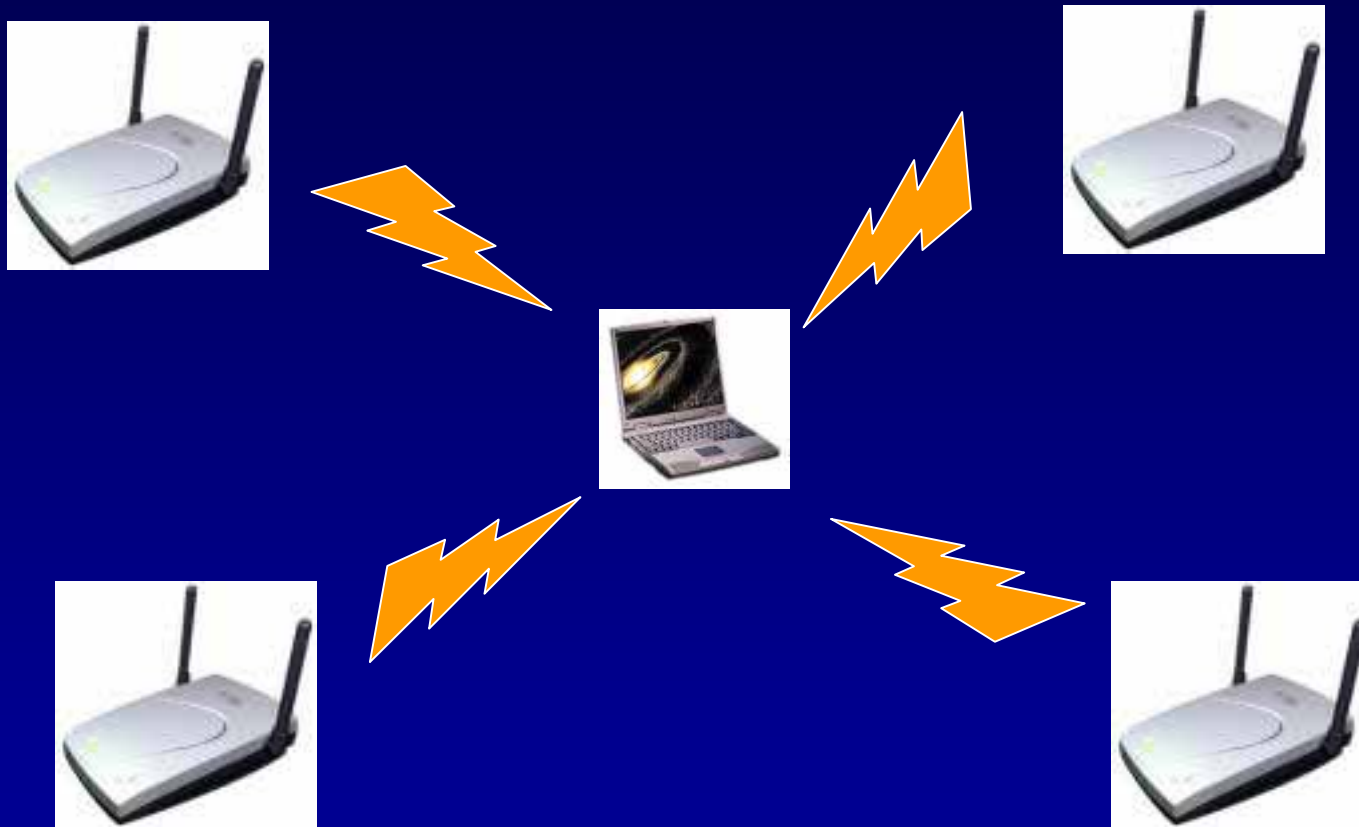
- **Issues**
  - ‣ Quality of voice in unlicensed bands (e.g.., ISM band) may tend to be noisy
  - ‣ Billing and Profit sharing
- Wi-Fi can be useful to cellular carriers to supplement cellular data offerings
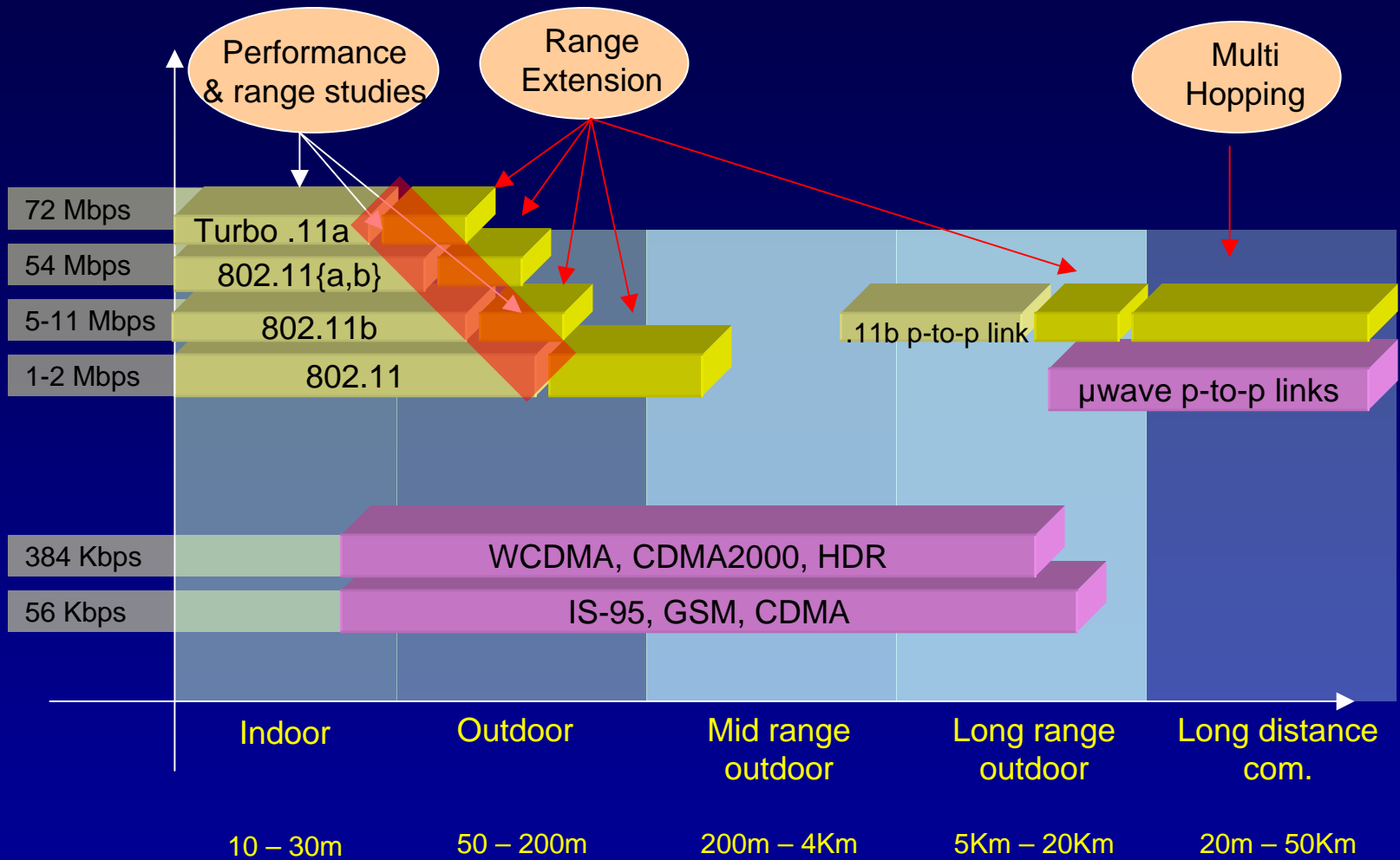
Location Enabled Networks

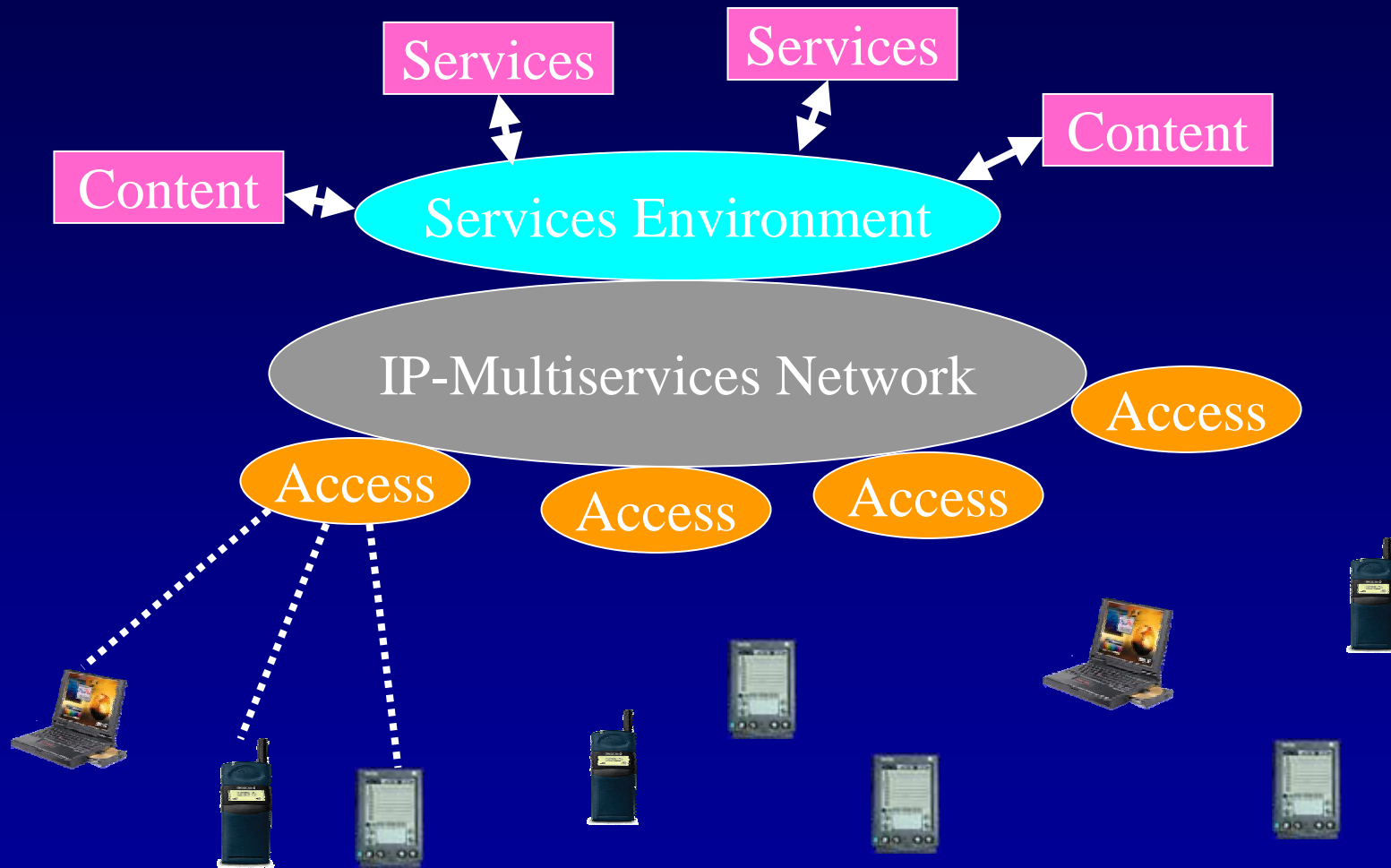Objective: to find the (x,y,z) co-ordinates of the device in the building

Question: Where is Student Z?
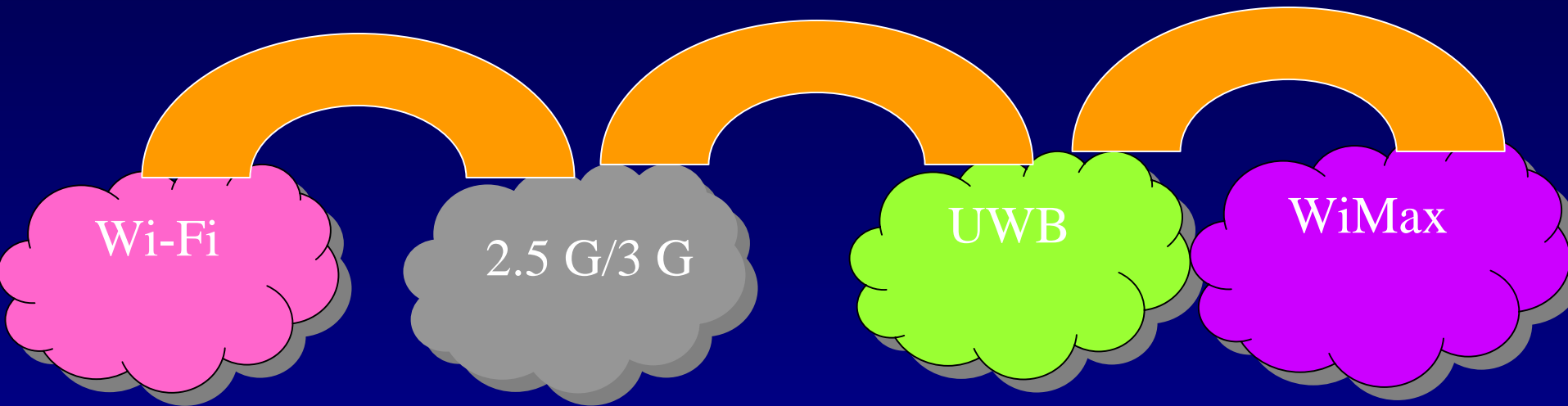Answer: Z is currently in front of Prof. Y's office

Research Program

The Future Environment

Services

Services

Content

Content

Services Environment

IP-Multiservices Network

Access

Access

Access

Access

Glimpse of the Future: Co-existence

Wi-Fi

2.5 G/3 G

UWB

WiMax

What are the Drivers for Change?

- Open software
- Worldwide standards
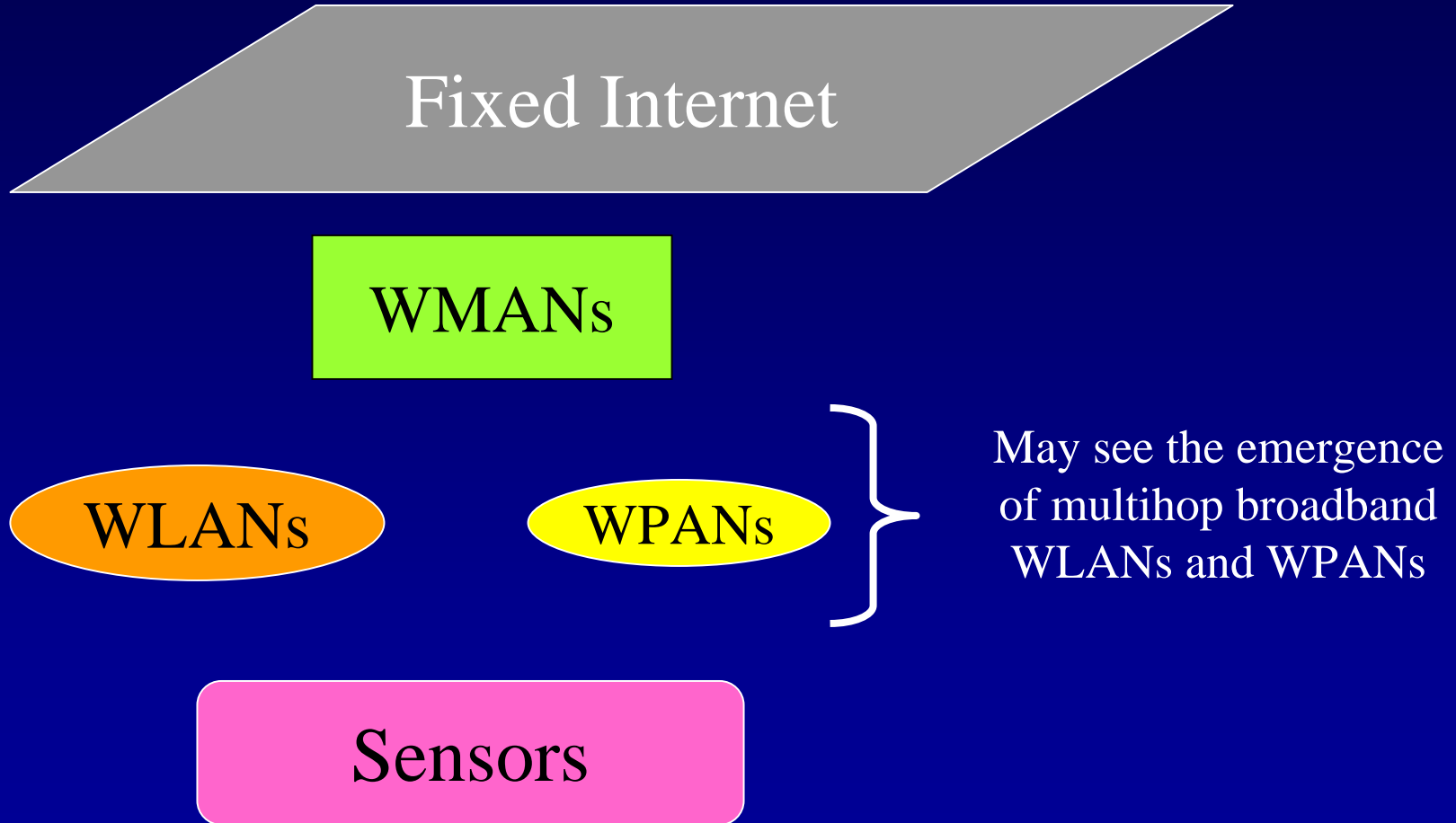- Increasing complexity
- …

Concluding Remarks: Technologies

- **IEEE 802.11**
  - ▸ Will continue to grow in
    - Public spaces, home, industry vertical, and enterprise market
  - ▸ 802.11 may provide a viable alternative to 3G in public places
  - ▸ 802.11 and 3G will be complementary and may not compete with each other !
  - ▸ Offers a great promise for bringing low cost networking services to the Asia/Pacific mass market
- **IEEE 802.16 promises to be of great interest in the "Broadband Wireless" space**

From Internet to Sensor Domains

Fixed Internet

WMANs

WLANs

WPANs

May see the emergence of multihop broadband WLANs and WPANs

Sensors

Concluding Remarks: Challenges

- Interoperability
  - Wi-Fi
  - 2.5G/3G
  - Wi-Max
- Billing and Pricing
- Performance and Capacity issues
  - How will layer 4 protocols perform over highly heterogeneous networks?
  - Quality of Service
- Security

Thank You

http://www.comp.nus.edu.sg/~rajeev/

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