

Mobile and WLAN technologies

Lecturer: Prof Xiaodong Chen

- ☐ **Introduction to Mobile/WLAN Technologies**
- ☐ **Overview of module organisation**

Age of Mobile Internet



iPhone 11

iPhone 11 Specs:

2G & 2.5G:

GSM/EDGE (850, 900, 1800, 1900 MHz)

3G & 3.5G:

TD-SCDMA 1900 (F), 2000 (A)

CDMA EV-DO Rev. A (800, 1900, 2100 MHz)

UMTS/HSPA+/DC-HSDPA (850, 900, 1700/2100, 1900, 2100 MHz)

4G:

FDD-LTE (Bands 1, 2, 3, 4, 5, 7, 8, 12, 13, 14, 17, 18, 19, 20, 25, 26, 29, 30, 66, 71)

TD-LTE (Bands 34, 38, 39, 40, 41, 42, 46, 48)

Gigabit-class LTE with 4x4 MIMO and LAA4

802.11ax Wi-Fi 6 with 2x2 MIMO

Bluetooth 5.0 wireless technology

Ultra Wideband chip for spatial awareness5

NFC with reader mode

Express Cards with power reserve

Installed all the technologies covered in this module!

History of Mobile Phones

EVOLUTION OF 1G TO 5G TECHNOLOGY



1G
1981



2G
1992



3G
2001



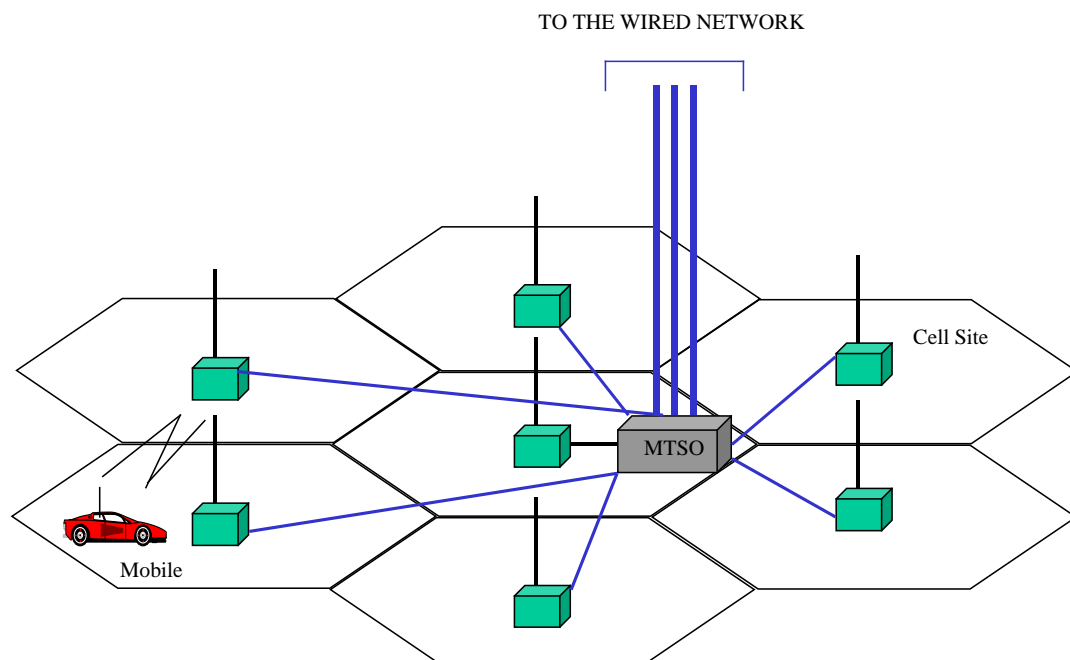
4G
2011



5G
2020

Evolution of Mobile Networks

1st Generation: analog – voice
AMPS(Advanced Mobile Phone Service) – FDMA



Martin Cooper
• **Inventor of cell phone**

Drawbacks:

- poor voice quality
- limited capacity
- manual roaming
- no security
- poor battery life

Evolution of Wireless Networks

2nd generation: digital – voice, text

- Cellular & PCS with seamless roaming and integrated paging
- IS-95 – narrowband CDMA
- IS-136, GSM –TDMA

- Low data rate!
- ...



3rd Generation

- Wide-area mobile: voice/data – smart phone
 - 2.5G: GPRS, EDGE (64–144 kbps)
 - 3G standards: (144kbps – 2mbps)
UMTS/IMT2000, Wideband CDMA, CDMA2000, TD-SCDMA
- High bandwidth requirement.



4th Generation – LTE/LTE-A

- **High speed data access (100Mbps – 1Gbps)**
 - Advanced antennas: MIMO
 - Signalling: OFDM
 - Features: MAGIC
 - » **M**obile Multimedia
 - » **A**n anywhere Anytime
 - » **G**lobal Mobility Support
 - » **I**ntegrated Wireless Solutions
 - » **C**ustomised Personal Services
 - Mobile Internet



Impact of Mobile Internet

4.4.2005

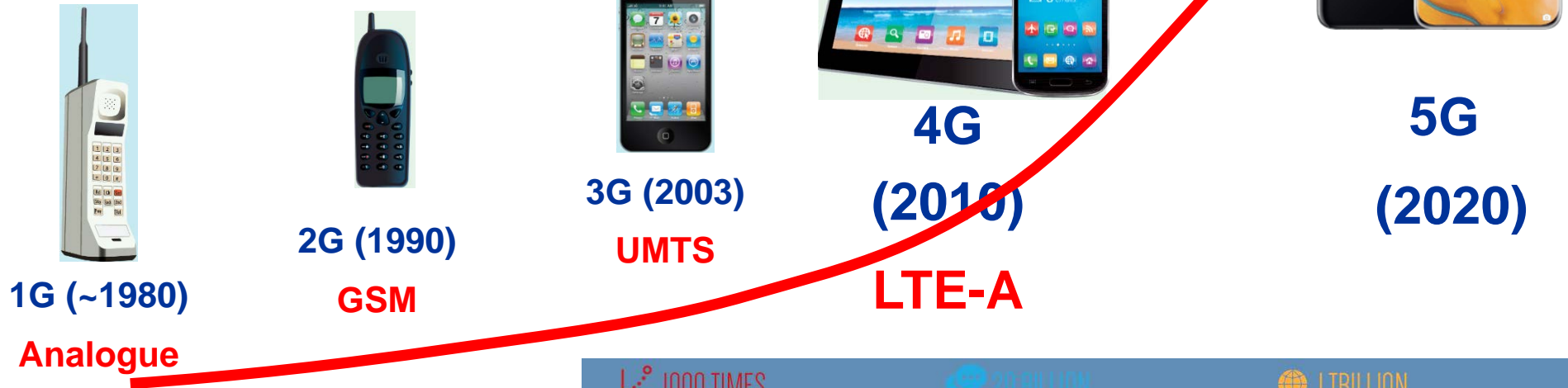


12.3.2013



What is your personal experience?

5th Generation Mobile Network



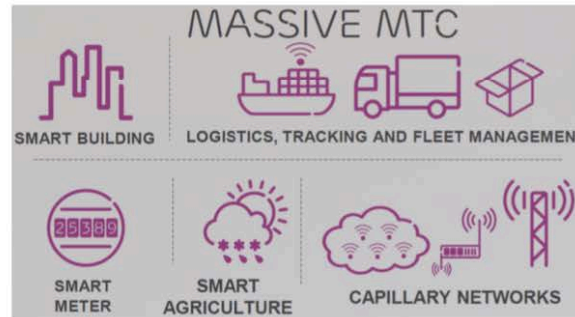
5G Initial Requirements

- Focus on “User Experience”
- Intelligent Terminal

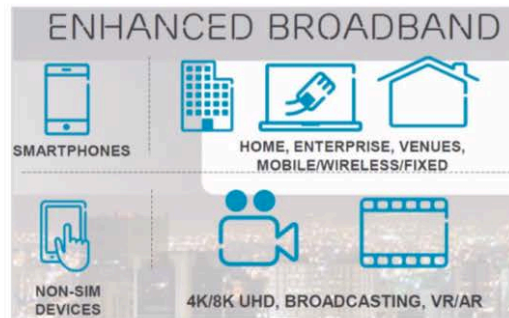


5G Application Scenarios

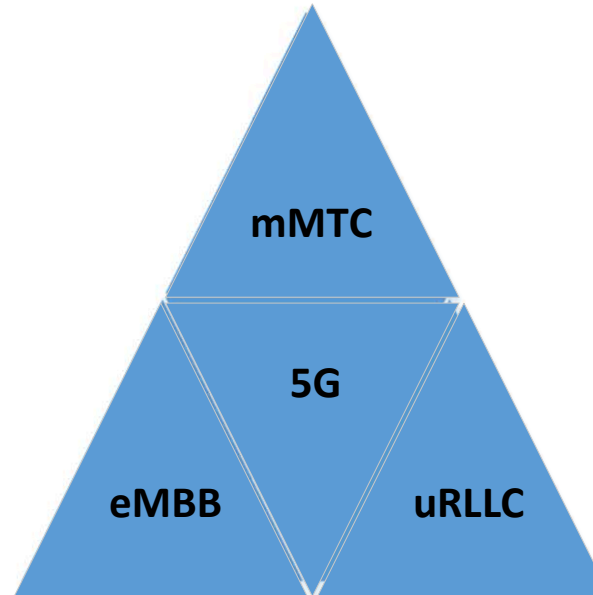
Low Cost
Low Energy
Low Data Volume
Large Numbers



Ultra Reliable,
Low Latency,
High availability



High Throughput
Low Latency



Intelligent Terminal

MTC – Machine Type of Communications

Figures from: H. Ji, et al. "Introduction to Ultra Reliable and Low Latency Communications in 5G", arXiv:1704.05565v1
O. Yilmaz, Ultra-Reliable and Low-Latency 5G Communication, EuCNC'16

Evolving of WLAN/Wi-Fi

THE EVOLUTION OF WI-FI

50 MILLION HOTSPOTS
WORLDWIDE

FRANCE (13M)
UNITED STATES (9.8M)
UNITED KINGDOM (5.6M)



1914 - 2000



THANK YOU HEDDY LAMAR

WITHOUT THE ACTOR HEDDY LAMAR, WE MIGHT NOT HAVE WI-FI.

DURING WWII SHE HELPED DEVELOP AN EARLY VERSION OF SPREAD SPECTRUM COMMUNICATION, PART OF THE BASIS FOR WIRELESS TECHNOLOGIES.

94% OF PEOPLE CITE WI-FI AS THE MOST IMPORTANT AMENITY IN A HOTEL



BUT ONLY 64% OF HOTELS OFFER IT

Mid 1990's

2000's

2010's

1997 (802.11)

BASIC WI-FI IS HERE!

The 802.11 committee established the IEEE802.11 set of standards to use when setting up a WLAN.

Most of the protocols established at this time, are no longer used today.

link speed was
2 Mbps

1999 (802.11B)

FIRST ROUTERS RELEASED

And Wi-Fi in the home was introduced. The Wi-Fi alliance was also formed and hired a company "Interbrand" to come up with a catchier name than IEEE802.11b Direct Sequence to market Wi-Fi.

They called it Wi-Fi (which stands for nothing.)

link speed rose to
11 Mbps

2003 (802.11G)

WI-FI TAKES OFF

Wireless connections started to catch up with wired connections with faster speeds and better distance coverage.

At this point, Wi-Fi was being implemented worldwide and being rapidly adopted by consumers.

Did you have the internet in 2003?

link speed rose to
54 Mbps

2009 (802.11N)

MIMO ARRIVES

The use of MIMO (multiple inputs, multiple outputs) was introduced to increase data speeds significantly without the need for higher bandwidth or power.

But, because it also meant more interference, the more expensive 5GHz became more attractive. With Wi-Fi now using both 2.4GHz and 5GHz, dual band routers were created so that devices could use either 5GHz or 2.4GHz to connect.

link speed rose to
600 Mbps

2012 (802.11AC)

BEAMFORM US UP, SCOTTIE.

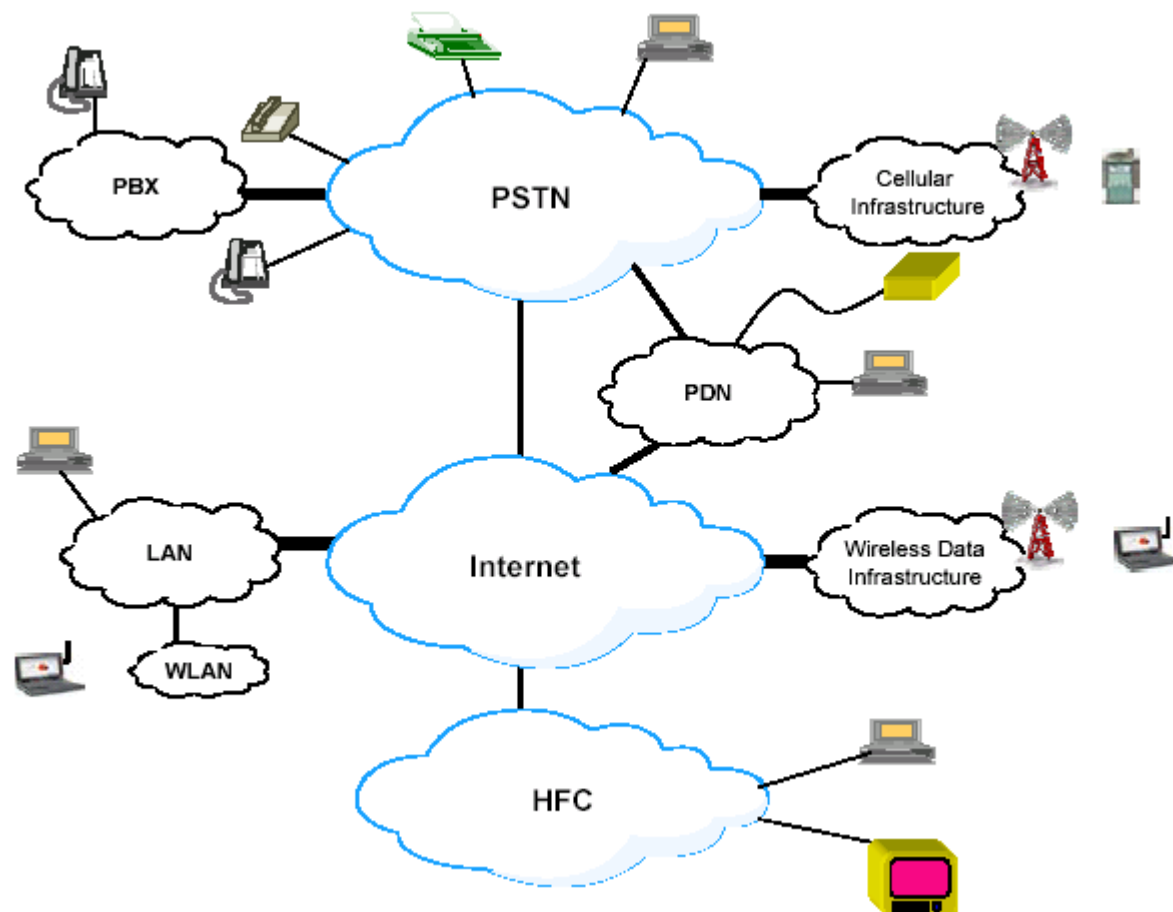
802.11ac became a superevo version of 802.11n, being the first protocol to reach link speeds into the gigabits per second range. To achieve this, it works strictly within the 5GHz band, uses massive amounts of bandwidth, operates in up to 8 spatial streams (MIMO), and uses beamforming.

Beamforming is a technology that essentially focuses signals and concentrates data transmissions, so more data reaches the target device instead of shooting out in all different directions.

link speed rose to
7 Gbps

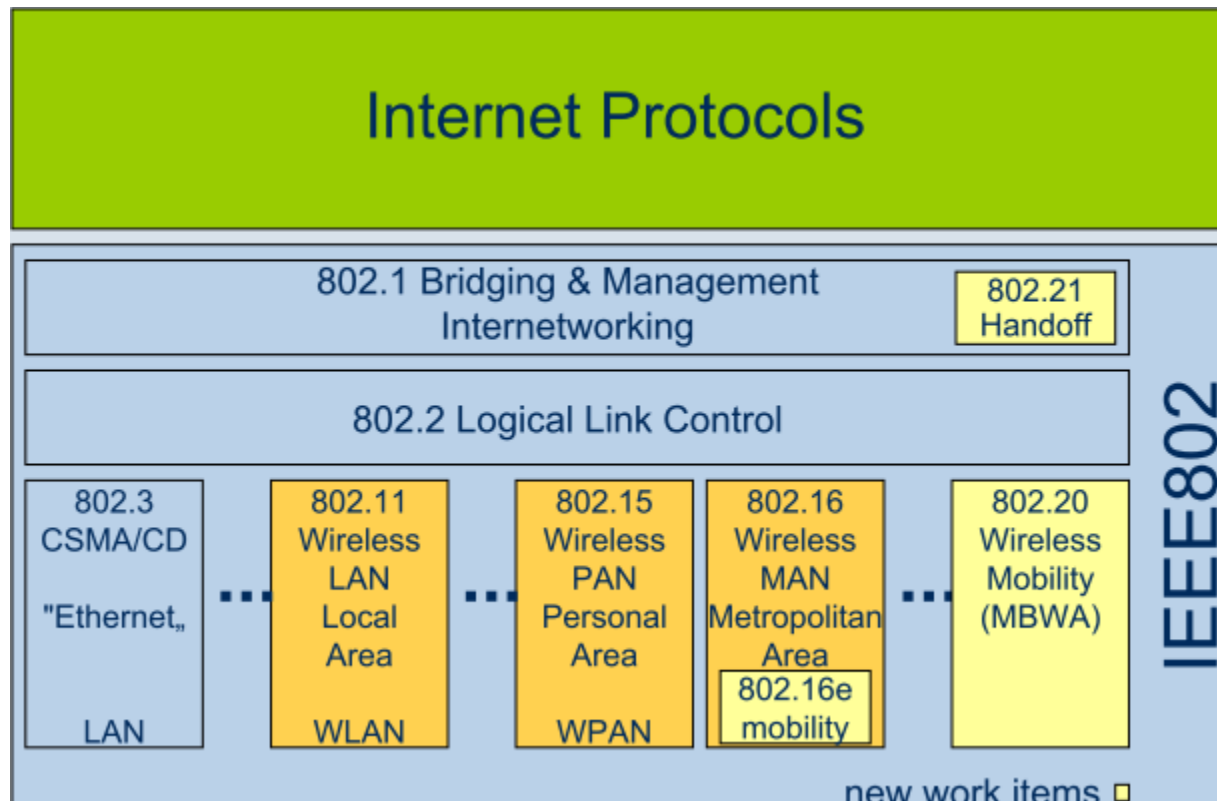
WI-FI UNDERWATER IS A CHALLENGE. SOUND WAVES IN WATER TRAVEL 100,000X SLOWER. IN THE MEANTIME, THE U.S NAVY SUPPLIES AN E-READER TO SAILORS THAT DOES NOT NEED WI-FI.

History of Internet



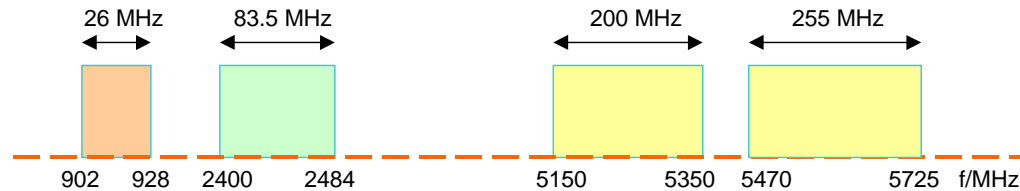
IEEE 802 Standards

- **IEEE 802.11x:**
 - Wireless LAN, also known as WiFi
- **IEEE802.15 covering:**
 - Bluetooth (802.15.1) and WiMedia (802.15.3) - Wireless PAN



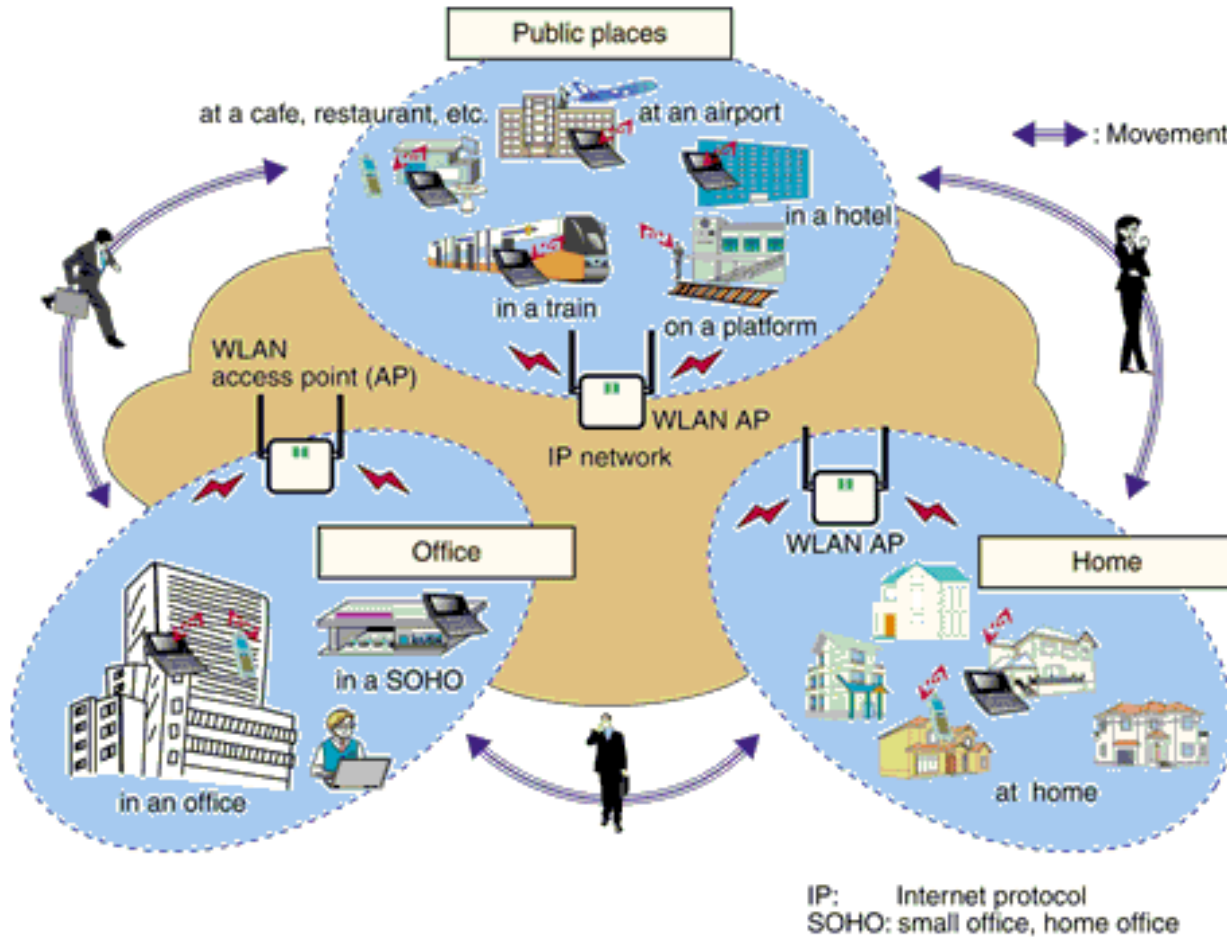
IEEE802 Spectrum

- **WLAN (IEEE802.11)**
 - ISM bands: 2.4 GHz and 5 GHz



- **Bluetooth (IEEE802.15.1)**
 - ISM band: 2.4 GHz
- **WiMedia (IEEE802.15.3)**
 - UWB bands: 3.1 – 10.6GHz in USA.

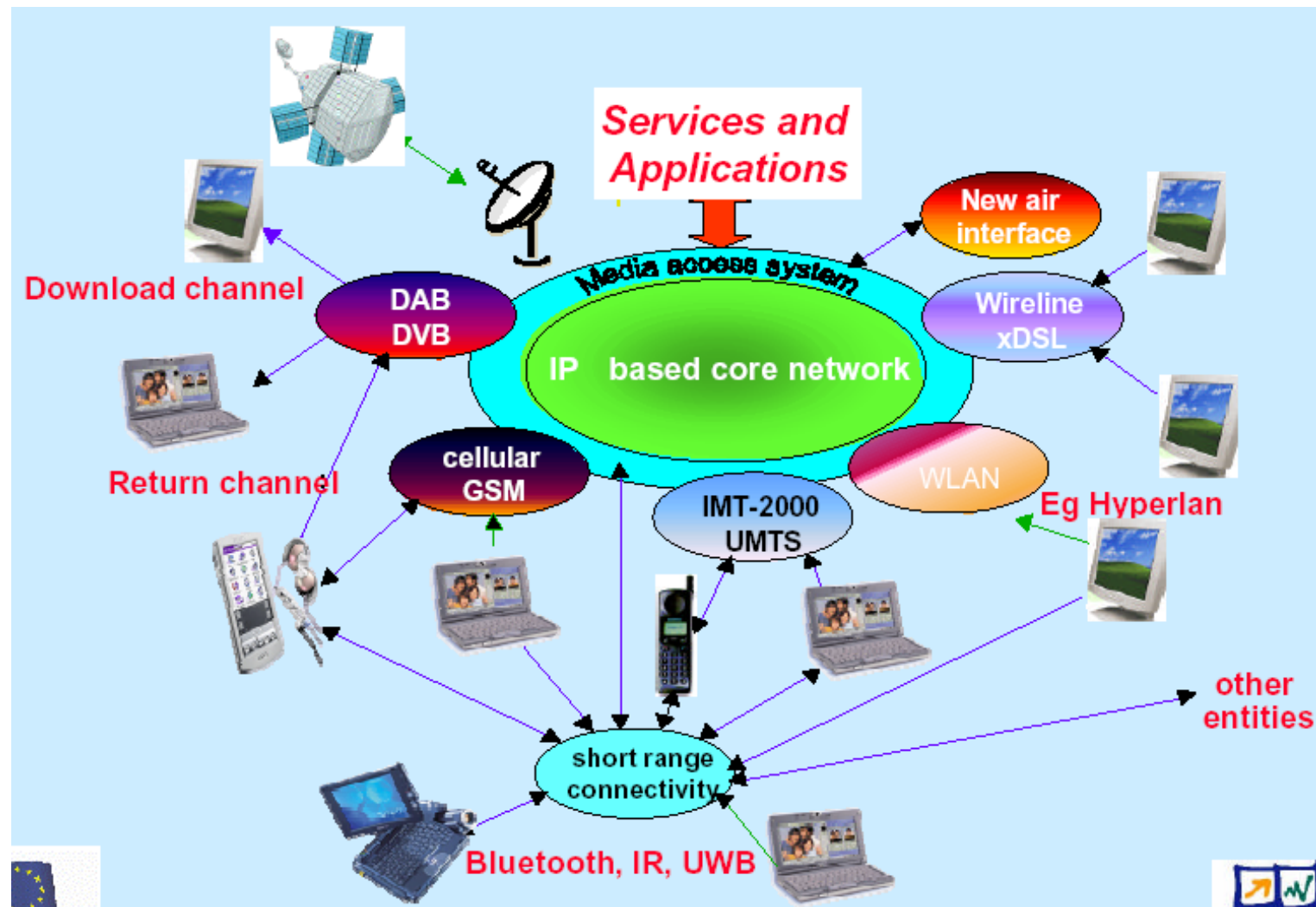
Wide IEEE802 Applications



Gigabit WLAN/WPAN

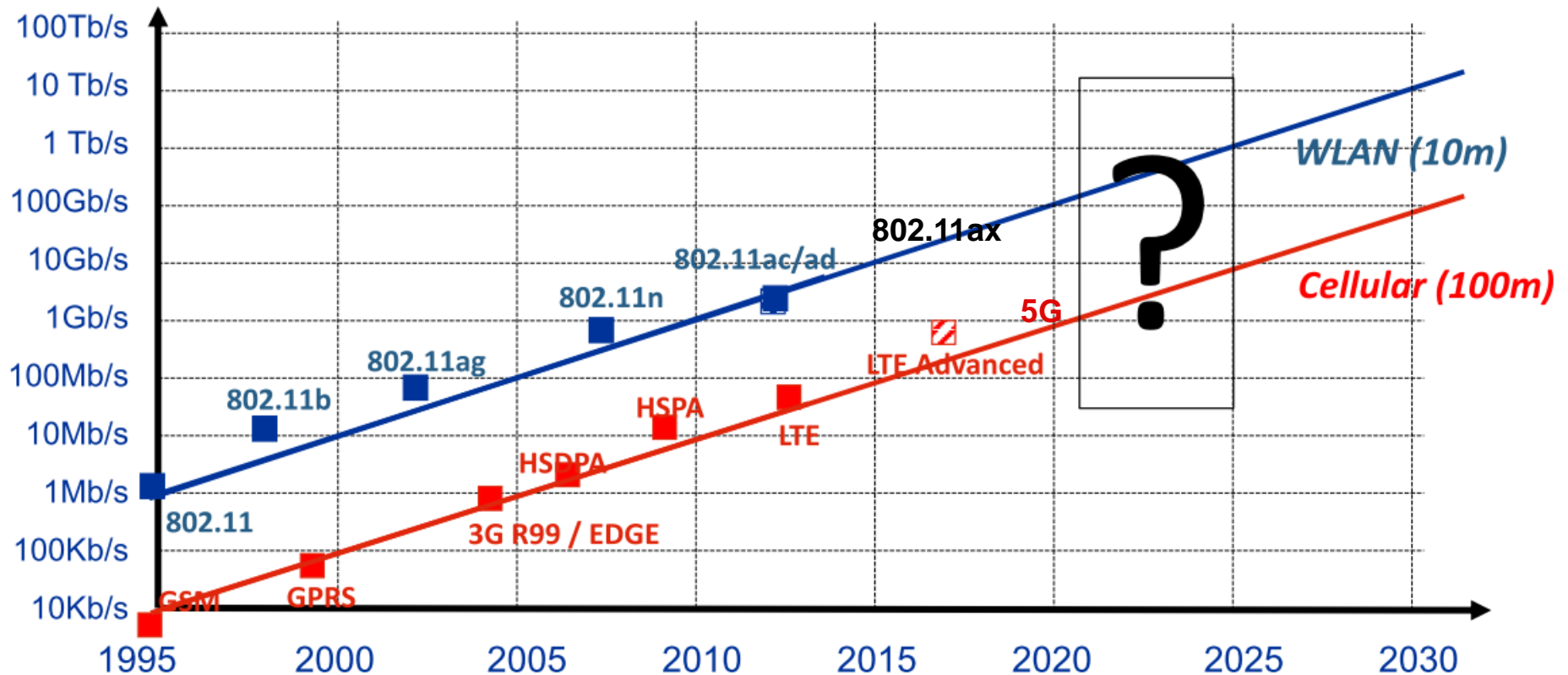
- **New Applications are fueling the need of high data rate WLAN/WPAN!**

Evolving Communication Networks



Core and Access Networks

Evolution of Wireless Networks



Question: 5G or 6G?

Generic Challenges in Wireless Access

▪ **Wireless Access**



**Mobility and Portability
(Anywhere and any time)**

Three fundamental issues:

1. **Wireless channel impairment solutions**
2. **Channel access (Multiple access)**
3. **Mobility management (handoff/handover)**

Other issues:

- **Data Rate and network capacity**
- **QoS for voice, data, multimedia traffics**
- **Power control (smooth operation and battery life)**
- **Privacy/security (encryption)**

Challenges in 5G

Support Diverse Use Cases & Requirements

1

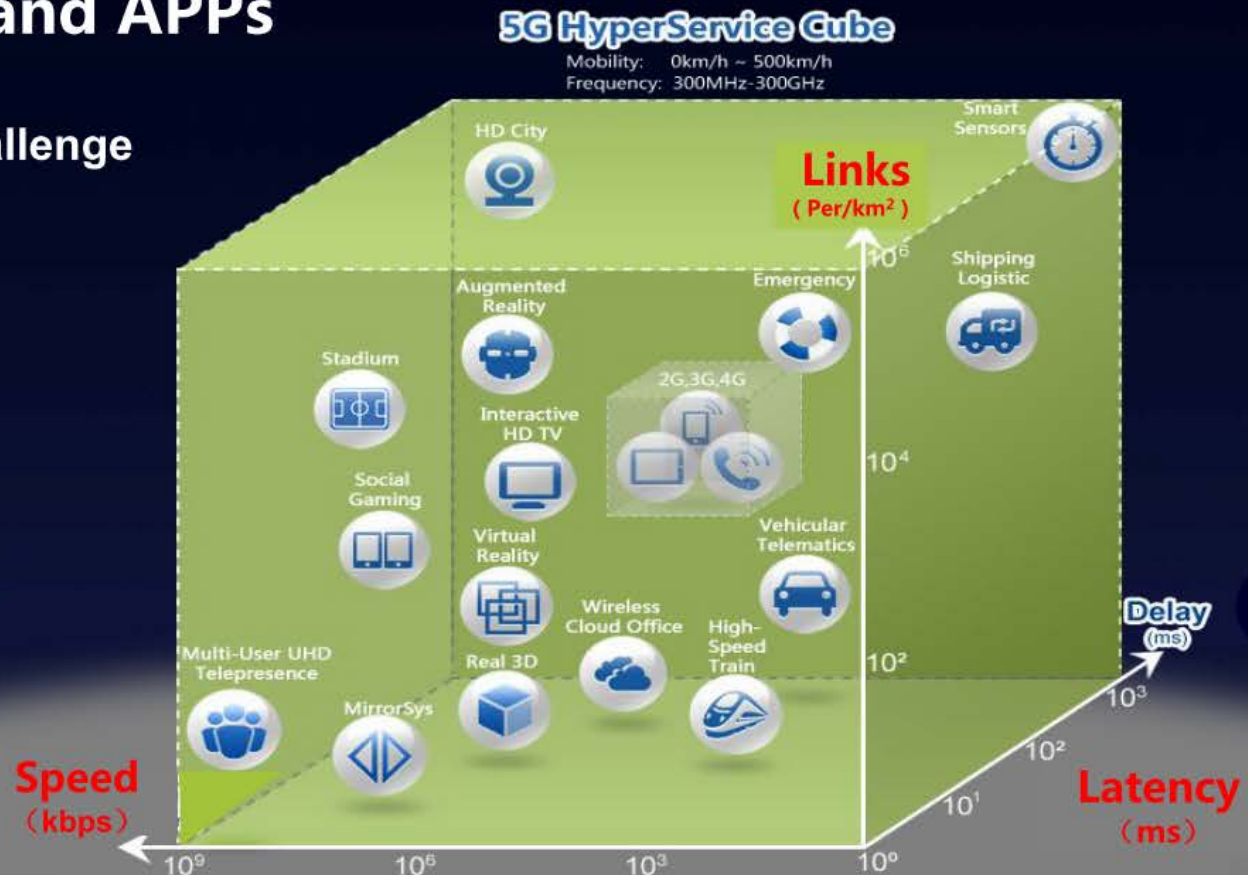
Beyond Internet Access and APPs

Unprecedented Performance Challenge

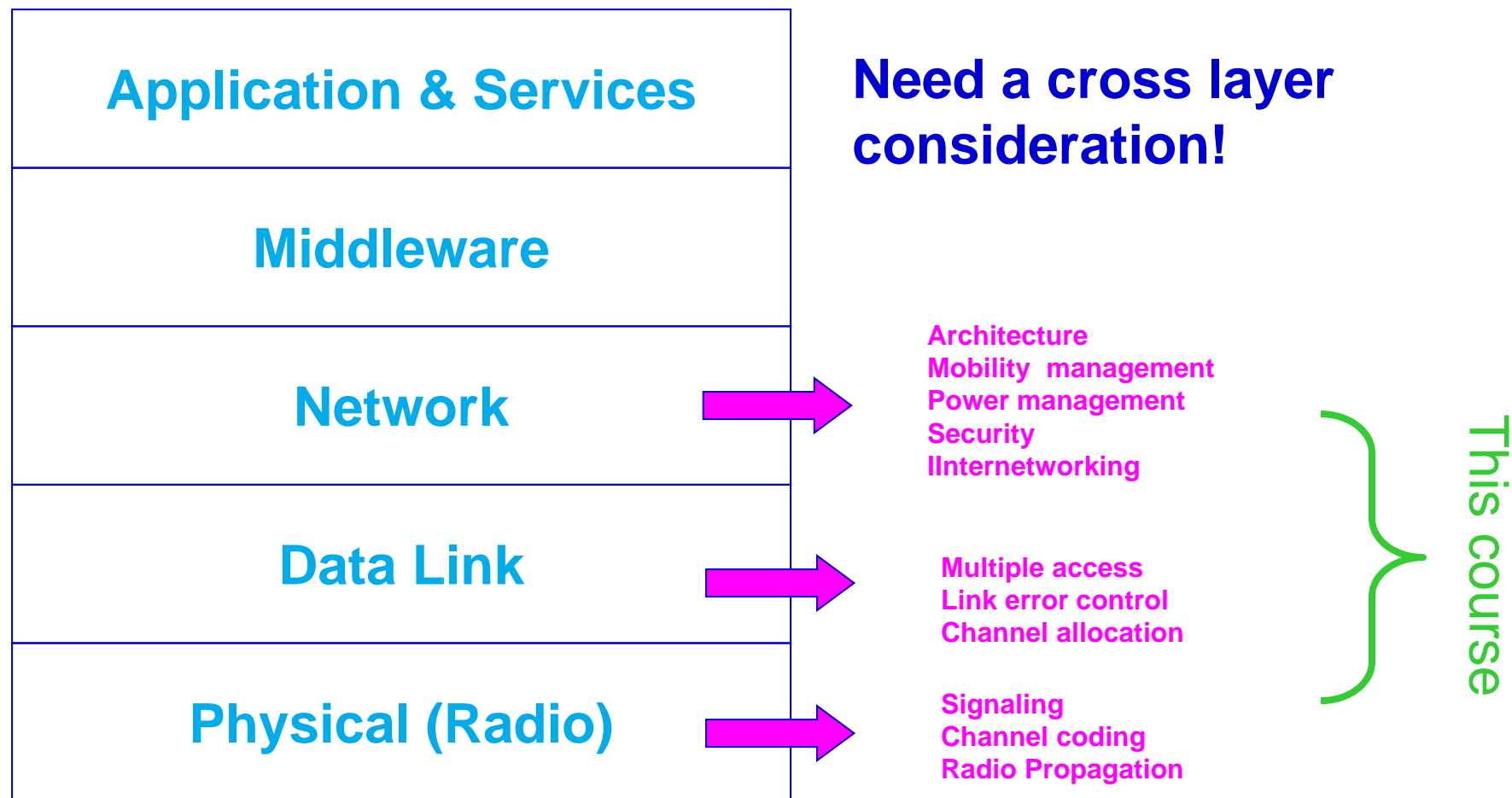
- Stretched in 3 Dimensions
 - Speed
 - Links
 - Response
- Spectrum Efficiency
- All Spectrum Access

Networks Re-Architect Challenge

- No-Cell Virtual RAN
- Software Defined & Simplicity
- Service Aware and Monetize

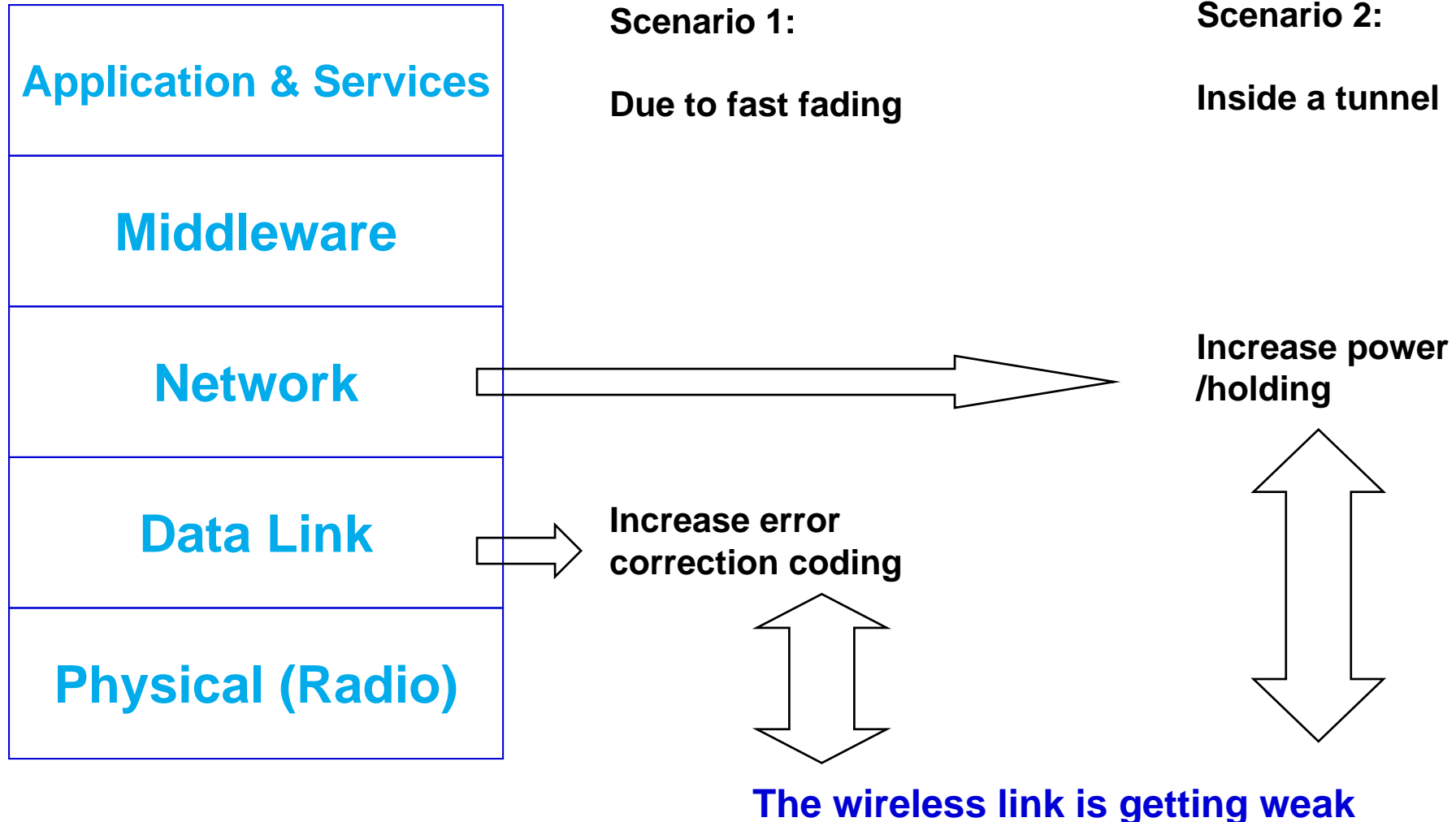


New Paradigm in Wireless System



A Standard Reference Protocol

A Case Study



Module Content

- Introduction to/Review of wireless fundamentals (1 week)
- Fundamentals of cellular system – First Generation(AMPS) (2 weeks)
- Key mobile systems (4 weeks)
 - Second Generation (GSM, CDMAONE, GPRS)
 - Third Generation systems (UMTS, CDMA2000) / (HSPA)
 - Fourth Generation: LTE/LTE Advanced
- Wireless Local Area Networks (WLAN) (3 weeks)
 - Main standards of WLANs (IEEE 802.11a/b/g/i/n/ac/ad/ax)
- Wireless Personal Area Networks (WPAN) (1 week)
 - Bluetooth 1.0, 2.0, 4.0 and 5.0

The weekly lecture plan is on the course page!

Module Assessment

- **Coursework (55%)**
 - Assignment on Cellular Networks (15%) in Weeks 4–6
 - WLAN Lab Exercise (WLAN) (14%) in Weeks 8 – 10
 - Automated Multiple Choice Questions – MCQ (26%) in Week 12
 - Open Book MCQ test in 60 min, 26 Questions
- **Final Exam (45%)**
 - 4 Questions, open book and online, January, 2021.
- **Class Quizzes (Formative Assessment)**
 - There will be a number of quiz questions at the end of each lecture for you to check your learning.
 - The answers can be found in the lecture and the teacher will also go through these questions during the reviewing part of the following lecture.

Module References

■ Main references

- K. Pahlavan and P. Krishnamurthy, Principles of Wireless Networks: A Unified Approach, Prentice Hall, 2002 (new version coming)
- William Stallings, Wireless Communications and Networks , Prentice Hall, 2002 (new version coming)
- 802.11 Wireless Networks: The Definitive Guide by Matthew Gast; O'Reilly Media; 2nd edition , 2005

■ Further readings:

- Garg, Wireless Communications and Networks, Morgan Kaufmann 2007, ISBN 978-0-12-373580-5.
- Mobile communications by Jochen Schiller; Second Edition; Addison-Wesley.
- WCDMA for UMTS – HSPA evolution and LTE by Harri Holma and Antti Toskala, 4th Edition, Wiley, 2007.
- HSDPA/HSUPA for UMTS: High Speed Radio Access for Mobile Communications by Harri Holma and Antti Toskala; Wiley, 2006.
- Wireless Local-area Network Fundamentals by Pejman Roshan and Jonathan Leary; Cisco Press; 1 edition, 2009.
- Cellular Communications Explained: From Basics to 3G by Ian Poole.
- T.S. Rappaport, Wireless Communications: Principles and practice, Second Edition, Prentice Hall, 2002.