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# Modern Wireless Networks

## Introduction



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ICEN 574– Spring 2019

Prof. Dola Saha

# Introductions

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## ➤ Instructor

- Prof. Dola Saha, PhD University of Colorado Boulder
- <http://www.albany.edu/faculty/dsaha/>
- <https://www.albany.edu/wwwres/facultyresearch/mesalabs/>
- [dsaha@albany.edu](mailto:dsaha@albany.edu)

## ➤ Students

# Information

➤ Course Website:

- [https://www.albany.edu/faculty/dsaha/teach/2019Spring\\_CEN574/2019Spring\\_CEN574.html](https://www.albany.edu/faculty/dsaha/teach/2019Spring_CEN574/2019Spring_CEN574.html)

➤ Blackboard:

- <https://blackboard.albany.edu/>

Course Website	Blackboard
Lecture Slides	Lab Assignments / Pre-Lab
Class Calendar / Schedule	Homework Assignments / Submission / Solution
Other Information	Announcements
	Grades

# Office Hours

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## Instructor

LI 88B

Tuesday – 12:00-1:00pm

Thursday – 12:00-1:00pm

By appointment



# Pre-Requisite

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- ICEN 472 Advanced Digital Communications
- ICEN 416 Computer Communication Networks
- The students are expected to be comfortable in
  - MATLAB
  - Unix/Linux environment

# Textbooks

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## ➤ Required:

- None

## ➤ Highly Recommended:

- Erik Dahlman, Stefan Parkvall and Johan Skold, "5G NR: The Next Generation Wireless Access Technology", First Edition, Elsevier, ISBN: 978-0-128-14323-0, 2018.
- Eldad Perahia and Robert Stacey, "Next Generation Wireless LANs: 802.11n and 802.11ac", Second Edition, Cambridge University Press, ISBN: 9781107016767, 2013.

## ➤ Reference:

- 3GPP Documents
- IEEE Standards for Wireless LANs

*Slides in this course will be taken from these books.*

# Assignments & Grading

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- Assignments
  - 4 Short Projects
- Grading
  - Each Short Project - 25%

# Grading Scale

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- A: 100-95 points A-: 94-90 points
- B+: 89-87 points B: 86-84 points B-: 83-80 points
- C+: 79-77 points C: 76-73 points C-: 72-70 points
- D+: 69-67 points D: 66-63 points D-: 62-60 points
- E: 59 points and below

# Academic Integrity

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- Undergraduate Academic Regulations
  - [http://www.albany.edu/undergraduate\\_bulletin/regulations.html](http://www.albany.edu/undergraduate_bulletin/regulations.html)
- Academic Dishonesty
  - Plagiarism, Cheating on examinations, unauthorized collaboration, etc.
- Practicing Academic Integrity
  - Citation
- Penalties for Violation
  - Zero in the assignment, lowering grade, failing grade, VAIR will be submitted

# What is Plagiarism?

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- Getting help from the Internet and not cite it
- Asking someone else to write the code for you
- Copying your friend's code – both the students are involved in plagiarism

# In Class Decorum

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- No use of phones
- No use of Computers / laptops
- Computers will be used only when directed in the class
- DO NOT browse random things in class
- No crosstalk
- No Food/Drink
- Raise hand to ask questions

# What will be covered?

## ➤ Recapitulation of Wireless Communication

	<b>Wireless Physical Layer</b>
Jan 29	Signal, Modulation, Coding, Channel Capacity
Jan 31	Doppler, Coherence Time, DSSS, CDMA, Access Methods
Feb 5	Signal Propagation, Pathloss, Shadowing, Multipath, Channel Models
Feb 7	OFDM, Channel Diversity, Beamforming, MIMO



# What will be covered?

## ➤ 3GPP World – OpenAirInterface for Project

	<b>Cellular Systems</b>
Feb 12	1G/2G/3G Systems, Cell, GSM, CDMA, Handoff
Feb 14	LTE - Architecture, Frame, Synchronization, RACH
Feb 19	OFDM, SC-FDMA, Space Time Coding
Feb 21	Packet Core – S-GW, P-GW
Feb 26	Mobility Management
Feb 28	PDCP, RLC, RRC, Control and Data Channel
Mar 5	Bearer Management, Hybrid ARQ
Mar 7	MU-MIMO, Precoding
Mar 12	Carrier Aggregation, CoMP, D2D
Mar 14	5G (5G NR, LTE for Massive MTC)

# What will be covered?

- Wireless LANs – Dissect Signals from 802.11 devices using SDRs

	<b>Wireless LANs</b>
Mar 26	PHY, MAC, PCF, DCF, IFS, Carrier Sense, Backoff
Mar 28	Synchronization, Association, 802.11a/b/g/n/ac
Apr 2	Enhanced DCF, Frame Aggregation, STBC
Apr 4	Channel Bonding, HT/VHT Frame, Preambles
Apr 9	MU-MIMO, Grouping
Apr 11	Tx Beamforming

# What will be covered?

## ➤ mmWave, Vehicular & IoT Comm – Setup LoRA Testbed

	<b>60GHz mmWave</b>
Apr 16	mmWave propagation and fading, 802.11ad standard
Apr 18	Beamforming protocol, Session transfer
	<b>Vehicular Networks</b>
Apr 23	802.11p, DSRC
Apr 25	Propagation, Routing
	<b>Communication for Internet of Things</b>
Apr 30	Bluetooth, BLE and iBeacon – PHY and MAC
May 2	802.15.4, Zigbee, Cluster Tree Network, UWB, Spread Spectrum
Mar 7	LPWAN – LoRA and SigFox

# Why this course?

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# Why this course?

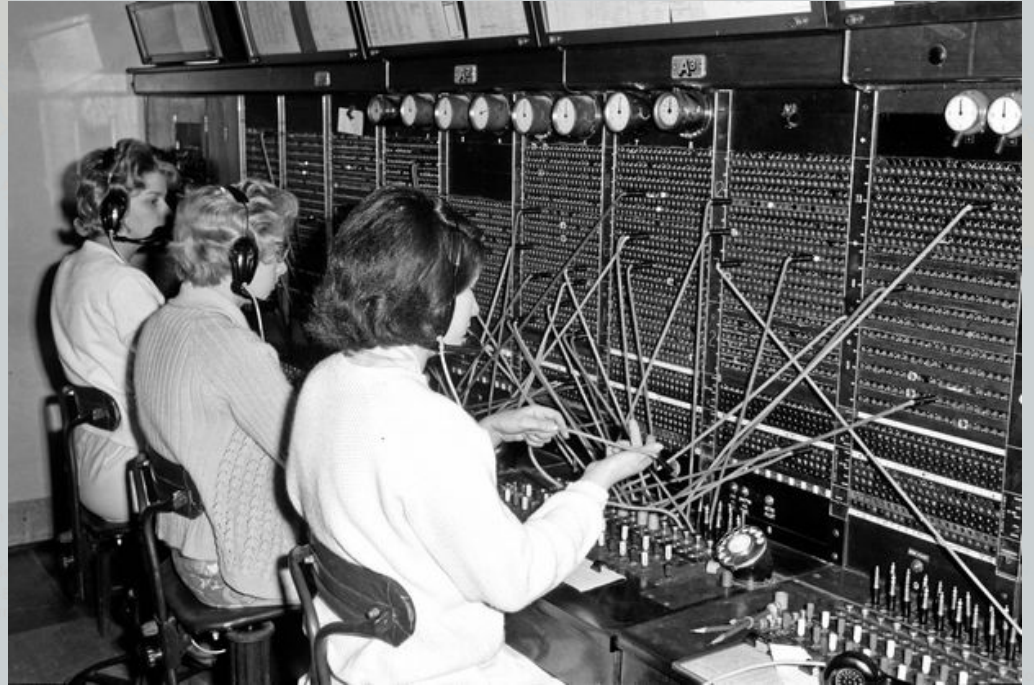
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- Prepare you for the industry



# 1970s – Trunk Call or Long Distance Calling

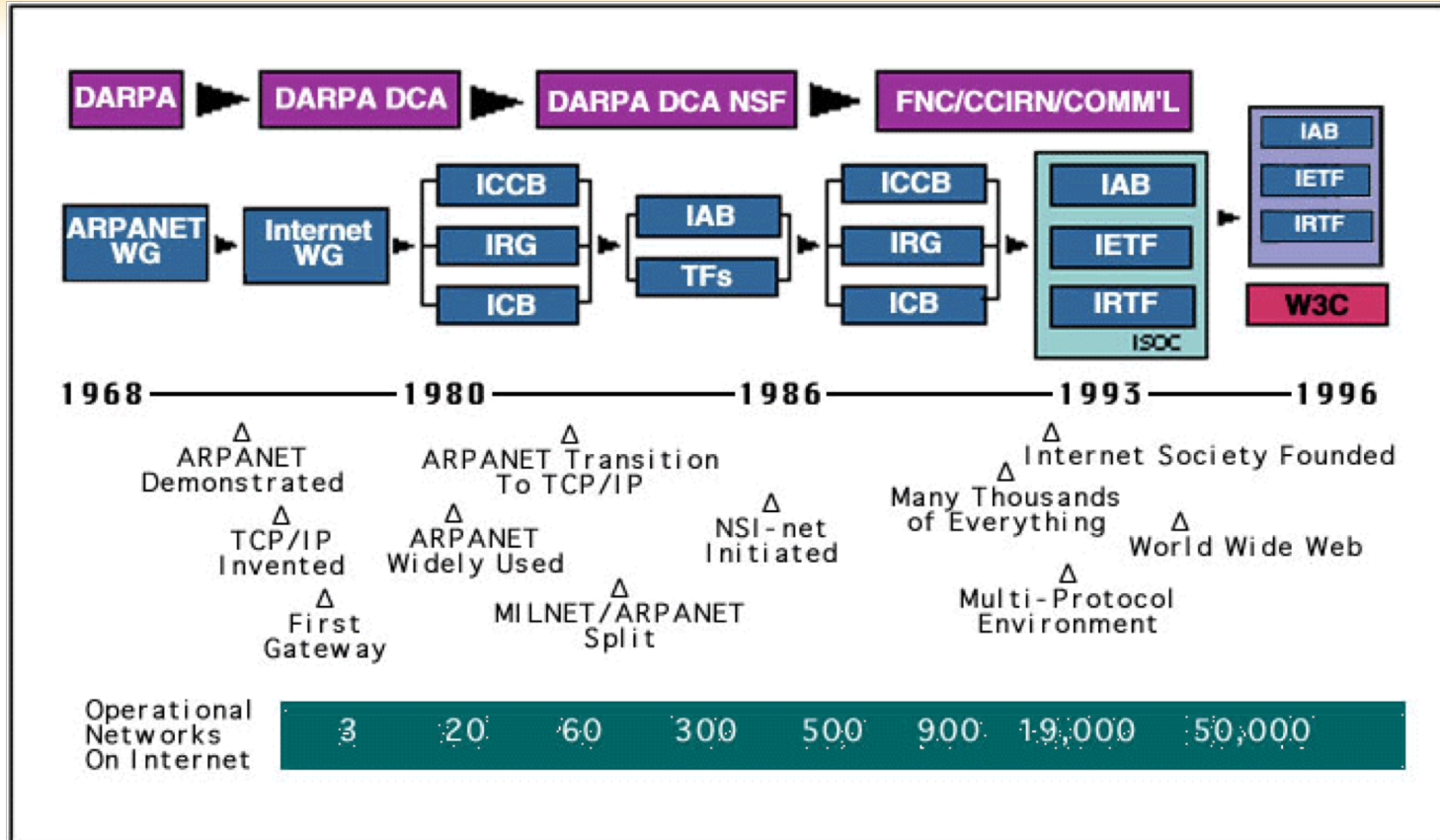
➤ 8:00AM – Call local exchange to setup a call to India



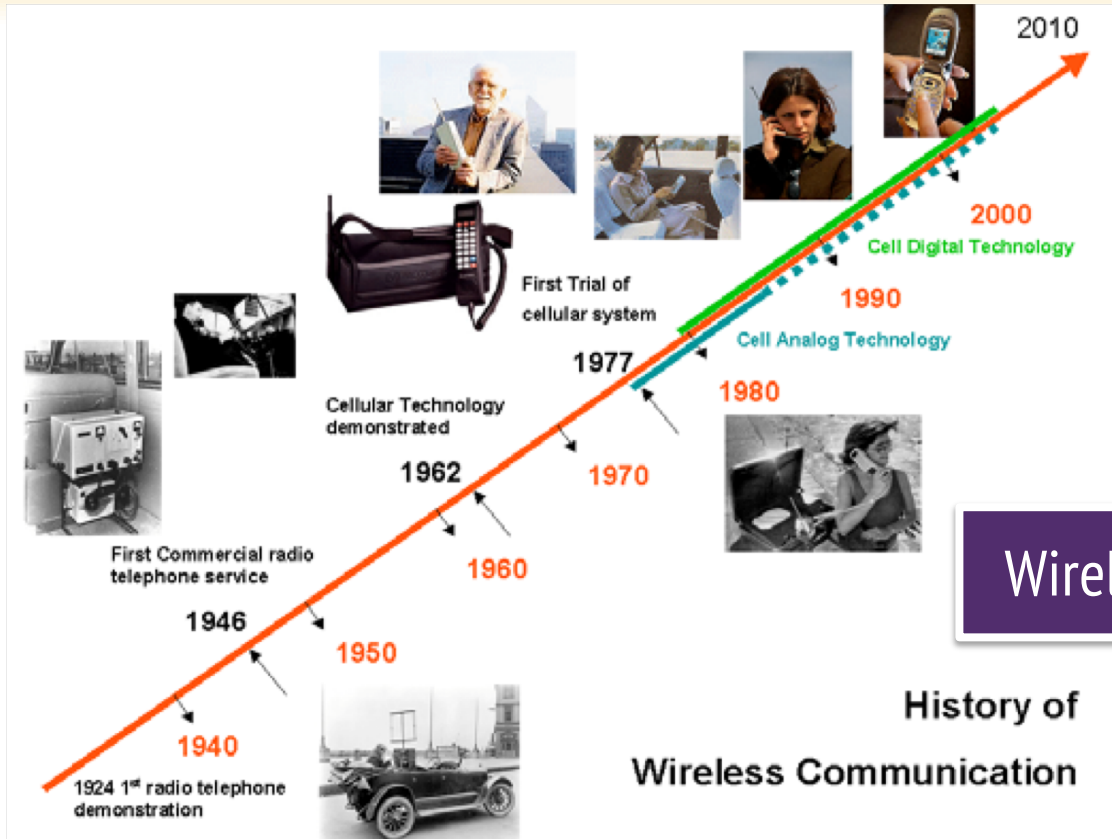
Circuit Switching

➤ 8:00PM – Transatlantic link setup

# A Brief History of the Internet

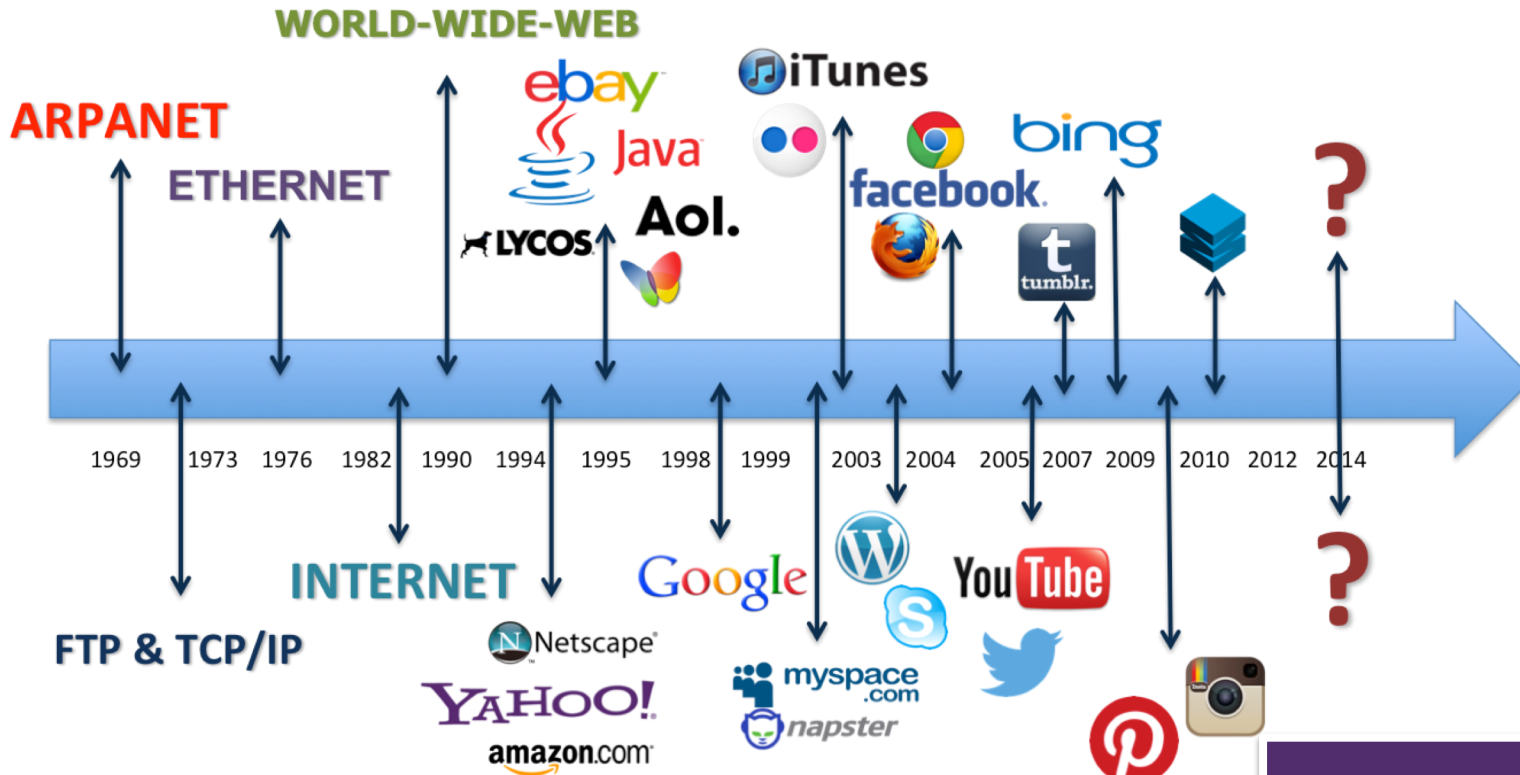


# A Brief History of Wireless Communication





# Growth of the Internet



Networks

# Advent of Smartphone



D'087 Patent  
Invention Date: April 20, 2006  
Priority Date: Jan 5, 2007

D'677 Patent  
Invention Date: April 20, 2006  
Priority Date: Jan 5, 2007

D'270 Patent  
Invention Date: Dec 13, 2006  
Priority Date: Aug 31, 2007

Wireless Networks  
Computer Architecture  
Embedded Systems

# Impact on our lives (1)





# Impact on our lives (2)

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# What's next? - Virtual Reality

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## ➤ Examples

- Remote concert
- VR enabled learning in classroom
- Telesurgery

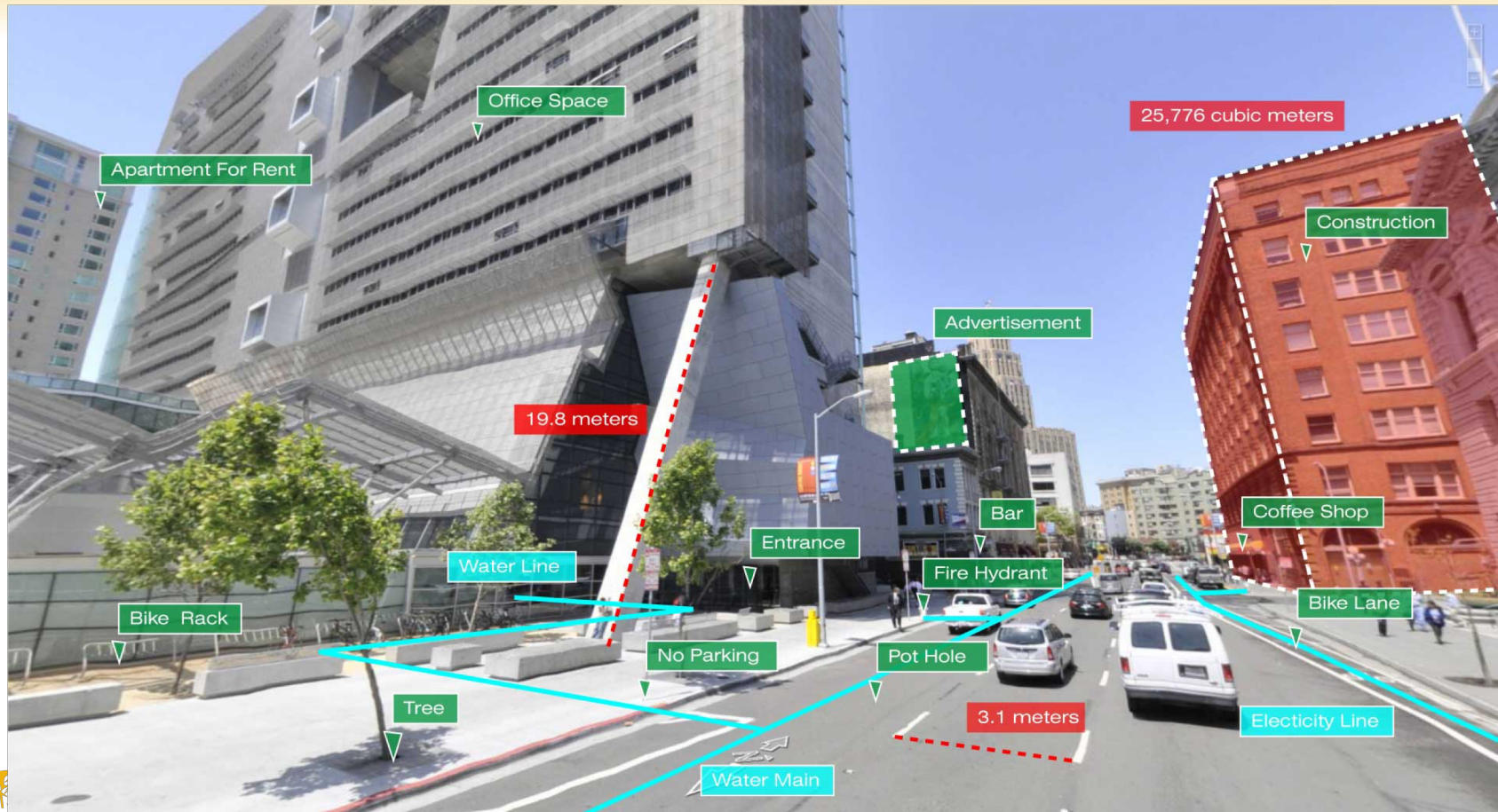
## ➤ Requirements

- Very high throughput
- Very low latency (<10ms)





# What's next? - Augmented Reality

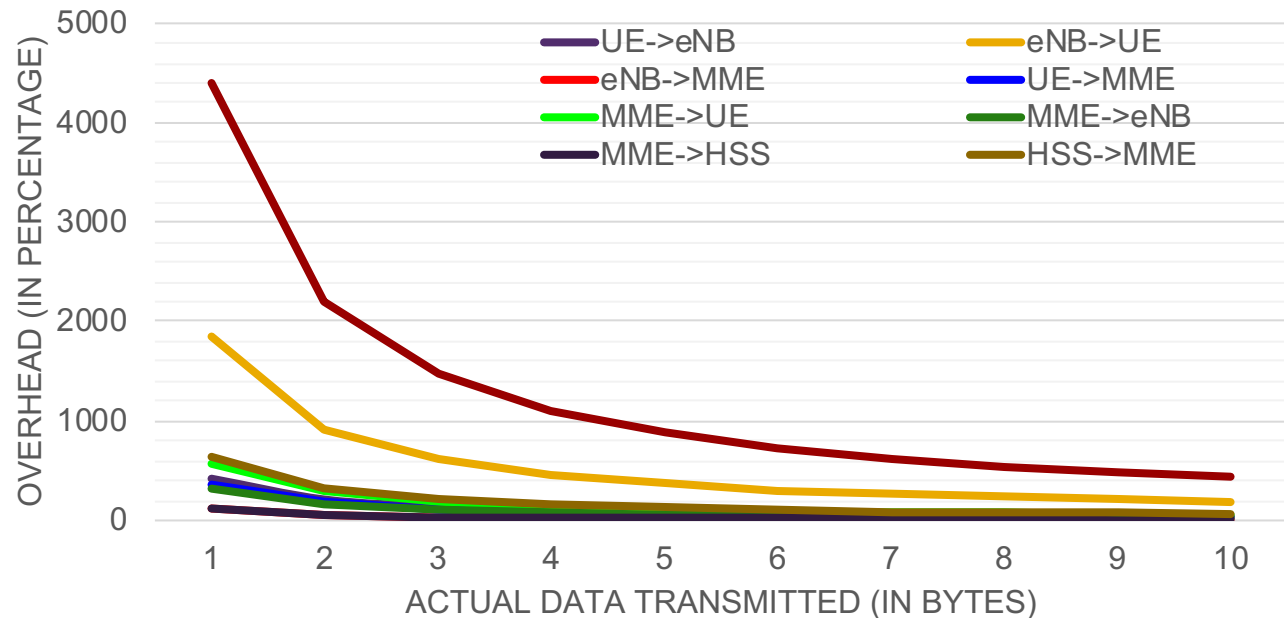


# Internet of Things

## ➤ What is different?

- Scale
- Dense
- Overhead
- Spurious
- Low latency (IIoT)

Percentage Overhead to setup a connection



# Challenges

- Speed of light = 299,792,458m/sec
- Transatlantic Links
  - 15,428 km → 5.1msec
  - 14,000 km → 5msec
  - 24,000 km → 8msec
- VR Requirement is end-to-end delay
  - <10ms
- We are limited by Physics!

15,428 Km



14,000 Km



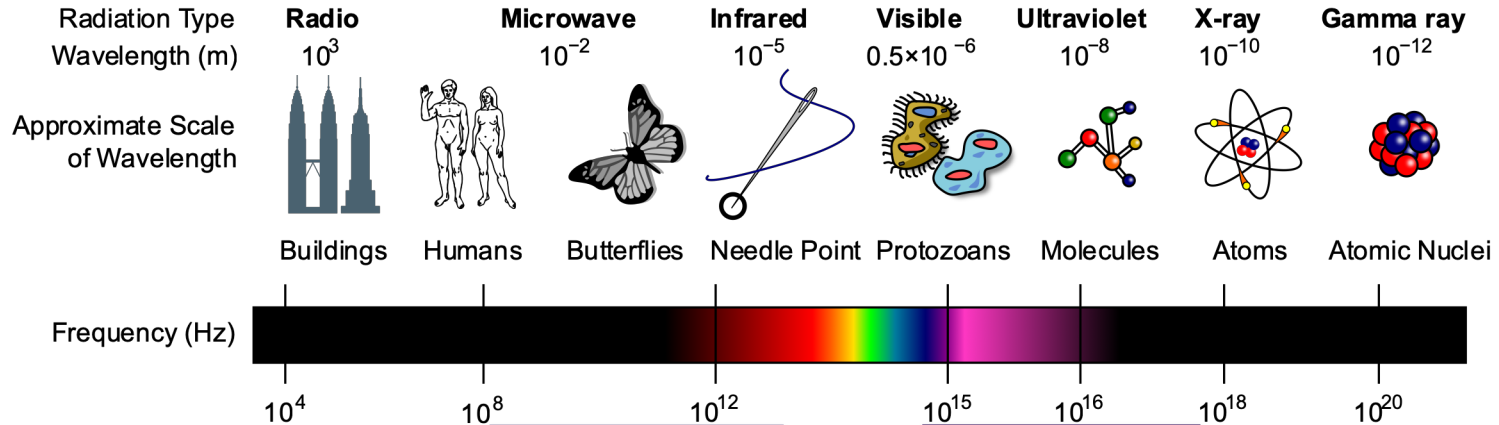
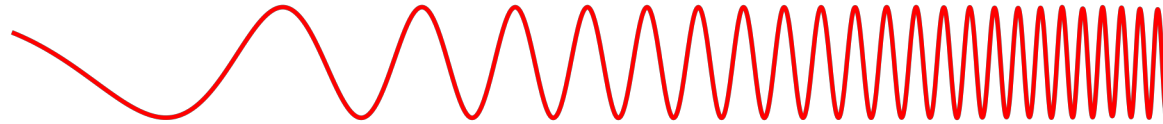
24,000 Km





# Future Wireless Frequencies

Penetrates Earth's Atmosphere?



Millimeter waves  
30-300GHz

Terahertz waves  
300GHz-3THz

mmWave Comm  
57-64GHz unlicensed, others

THz Comm  
0.1-10THz

Visible Light Comm  
430-700THz

# Different in New Spectrum

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- Pathloss / Penetration
- Smaller Antenna Size
- Massive MIMO – higher capacity
- Directional beam – spatial reuse
- Beamforming and Beam tracking
- Handover
- Localization

# Introduction to Standards

- The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners” and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.
- The original scope of 3GPP (1998) was to produce Technical Specifications and Technical Reports for a 3G Mobile System based on evolved GSM core networks and the radio access technologies that they support (i.e., Universal Terrestrial Radio Access (UTRA) both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes).



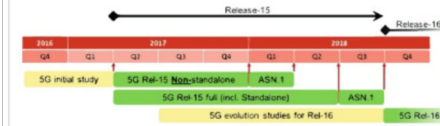
A GLOBAL INITIATIVE

June 2018, for 5G World Summit



## Early progress on 5G Specifications

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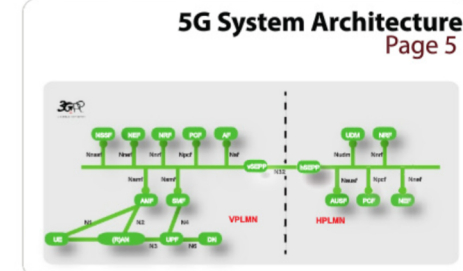
## IMT-2020 Status

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### Mission Critical Services in 3GPP

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## About 3GPP

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- 1 Specifications
- 2 Change Requests
- 3 Release Freeze Dates
- 4 Three-Stage Methodology
- 5 Working Group Structure
- 6 Members and Officials

# Introduction to Standards

## ➤ IEEE Standards Association

IEEE Standard for Information technology—  
Telecommunications and information exchange between systems  
Local and metropolitan area networks—  
Specific requirements

### Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

IEEE Computer Society

Sponsored by the  
LAN/MAN Standards Committee

IEEE  
3 Park Avenue  
New York, NY 10016-5997  
USA

IEEE Std 802.11™-2016  
(Revision of  
IEEE Std 802.11-2012)