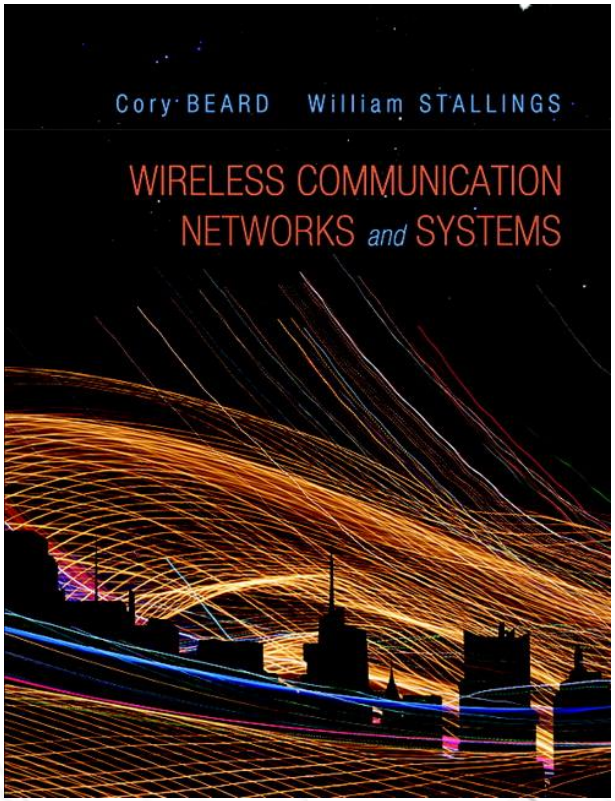
CHAPTER 1
INTRODUCTION



Wireless Communication Networks and Systems

1st edition

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WIRELESS COMES OF AGE

- Guglielmo Marconi invented the wireless telegraph in 1896
  - Communication by encoding alphanumeric characters in analog signal
  - Sent telegraphic signals across the Atlantic Ocean
- Communications satellites launched in 1960s
- Advances in wireless technology
  - Radio, television, mobile telephone, mobile data, communication satellites
- More recently
  - Wireless networking, cellular technology, mobile apps, Internet of Things

CELLULAR TELEPHONE

- Started as a replacement to the wired telephone
- Early generations offered voice and limited data
- Current third and fourth generation systems
  - Voice
  - Texting
  - Social networking
  - Mobile apps
  - Mobile Web
  - Mobile commerce
  - Video streaming

WIRELESS IMPACT

- Profound
- Shrinks the world
- Always on
- Always connected
- Changes the way people communicate
  - Social networking
- Converged global wireless network

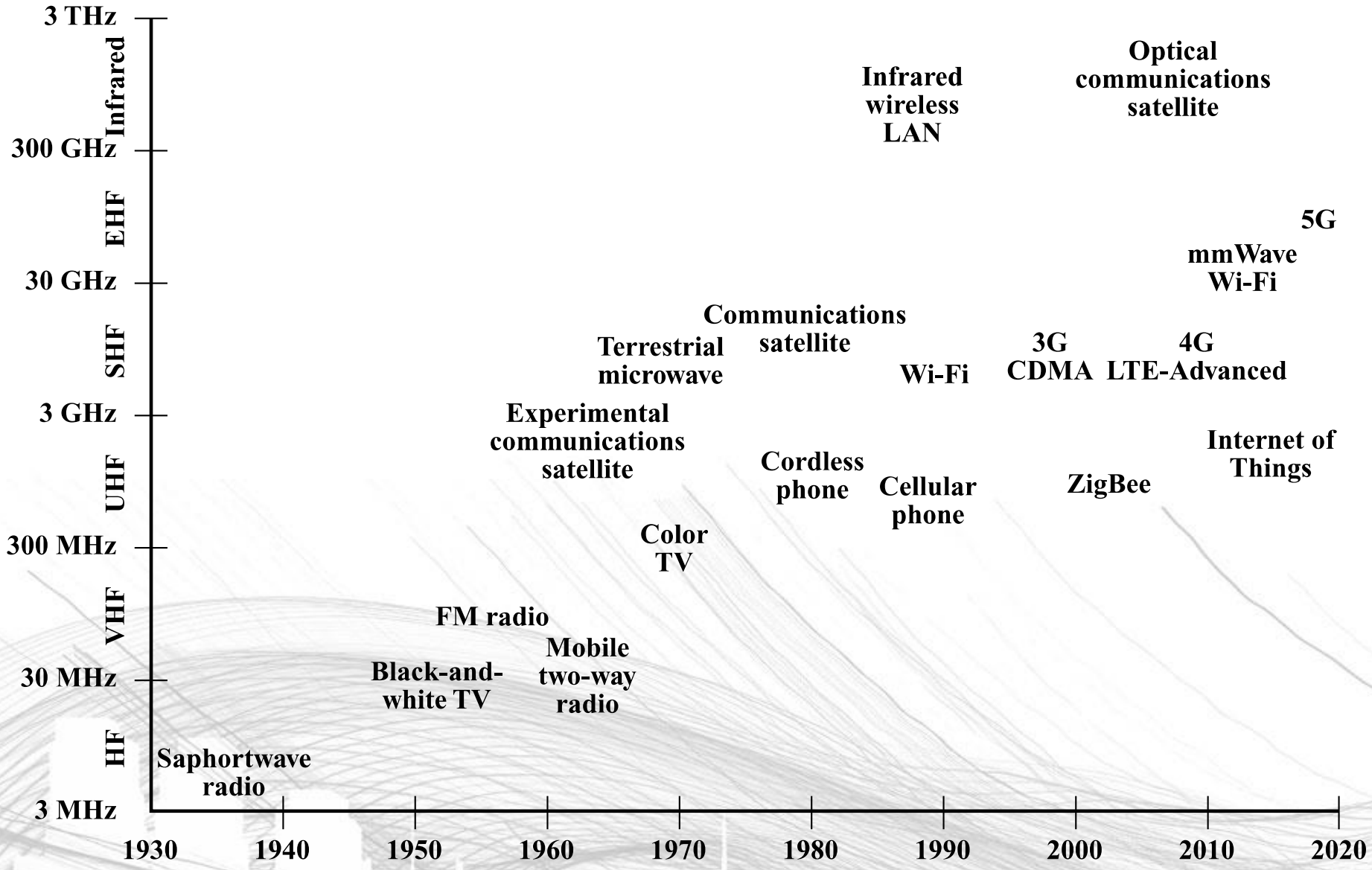


FIGURE 1.1 SOME MILESTONES IN WIRELESS COMMUNICATIONS

GLOBAL CELLULAR NETWORK

- Growth
  - 11 million users in 1990
  - Over 7 billion today
- Mobile devices
  - Convenient
  - Location aware
  - Only economical form of communications in some places

GLOBAL CELLULAR NETWORK

- Generations
  - 1G – Analog
  - 2G – Digital voice
    - Voice services with some moderate rate data services
  - 3G – Packet networks
    - Universal Mobile Phone Service (UMTS)
    - CDMA2000
  - 4G – New wireless approach (OFDM)
    - Higher spectral efficiency
    - 100 Mbps for high mobility users
    - 1 Gbps for low mobility access
    - Long Term Evolution (LTE) and LTE-Advanced

MOBILE DEVICE REVOLUTION

- Originally just mobile phones
- Today's devices
  - Multi-megabit Internet access
  - Mobile apps
  - High megapixel digital cameras
  - Access to multiple types of wireless networks
    - Wi-Fi, Bluetooth, 3G, and 4G
  - Several on-board sensors
- Key to how many people interact with the world around them

MOBILE DEVICE REVOLUTION

- Better use of spectrum
- Decreased costs
- Limited displays and input capabilities
- Tablets provide balance between smartphones and PCs
- Long distance
  - Cellular 3G and 4G
- Local areas
  - Wi-Fi
- Short distance
  - Bluetooth, ZigBee

FUTURE TRENDS

- LTE-Advanced and gigabit Wi-Fi now being deployed
- Machine-to-machine communications
  - The “Internet of Things”
  - Devices interact with each other
    - Healthcare, disaster recovery, energy savings, security and surveillance, environmental awareness, education, manufacturing, and many others
  - Information dissemination
    - Data mining and decision support
  - Automated adaptation and control
    - Home sensors collaborate with home appliances, HVAC systems, lighting systems, electric vehicle charging stations, and utility companies.
  - Eventually could interact in their own forms of social networking

FUTURE TRENDS

- Machine-to-machine communications
  - 100-fold increase in the number of devices
  - Type of communication would involve many short messages
  - Control applications will have real-time delay requirements
    - Much more stringent than for human interaction

FUTURE TRENDS

- Future networks
  - 1000-fold increase in data traffic by 2020
  - 5G – Being defined; envisioned by 2020
- Technologies
  - Network densification – many small cells
  - Device-centric architectures - focus on what a device needs
  - Massive multiple-input multiple-output (MIMO) – 10s or 100s of antennas
    - To focus antenna beams toward intended devices
  - Millimeter wave (mmWave) - frequencies in the 30 GHz to 300 GHz bands
    - Have much available bandwidth.
    - But require more transmit power and have higher attenuation due to obstructions
  - Native support for machine to machine communication
    - Sustained low data rates, massive number of devices, and very low delays.

THE TROUBLE WITH WIRELESS

- Wireless is convenient and less expensive, but not perfect
- Limitations and political and technical difficulties inhibit wireless technologies
- Wireless channel
  - Line-of-sight is best but not required
  - Signals can still be received
    - Transmission through objects
    - Reflections off of objects
    - Scattering of signals
    - Diffraction around edges of objects

THE TROUBLE WITH WIRELESS

- Wireless channel
  - Reflections can cause multiple copies of the signal to arrive
    - At different times and attenuations
    - Creates the problem of *multipath fading*
    - Signals add together to degrade the final signal
  - Noise
  - Interference from other users
  - Doppler spread caused by movement

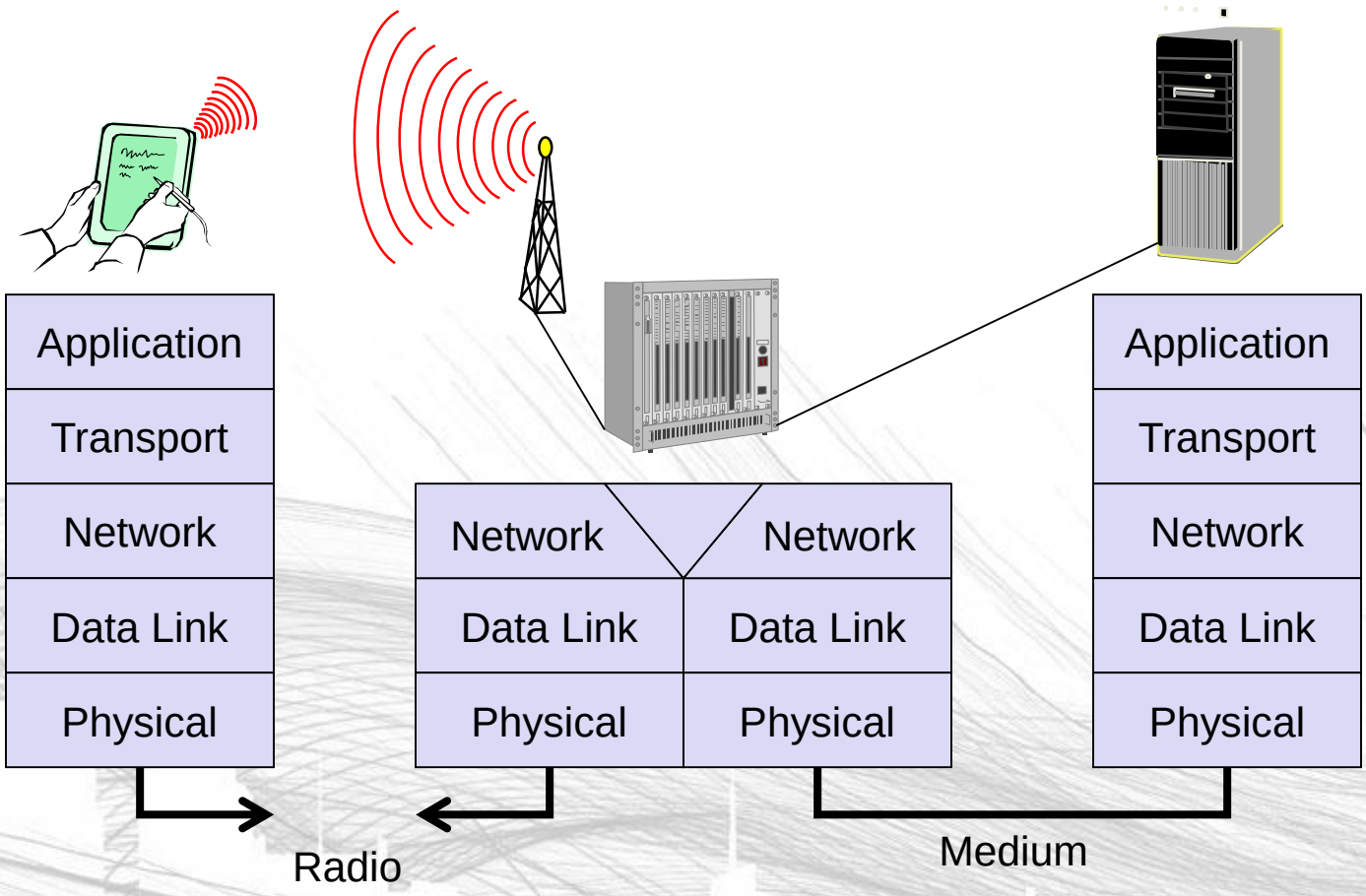
COMBATING PROBLEMS

- Modulation – use a signal format to send as many bits as possible
- Error control coding – add extra bits so errors are detected/corrected.
- Adaptive modulation and coding – dynamically adjust modulation and coding to current channel conditions.
- Equalization – counteract the multipath effects of the channel.
- Multiple-input multiple-output systems – use multiple antennas
  - Point signals strongly in certain directions
  - Send parallel streams of data.
- Direct sequence spread spectrum – expand the signal bandwidth
- Orthogonal frequency division multiplexing – break a signal into many lower rate bit streams
  - Each is less susceptible to multipath problems.

POLITICAL DIFFICULTIES

- Between companies
  - Need common standards so products interoperate
  - Some areas have well agreed-upon standards
    - Wi-Fi, LTE
    - Not true for Internet of Things technologies
- Spectrum regulations
  - Governments dictate how spectrum is used
    - Many different types of uses and users
  - Some frequencies have somewhat restrictive bandwidths and power levels
    - Others have much more bandwidth available

PROTOCOL REFERENCE MODEL



PROTOCOL LAYER MODEL

Application layer	service location new/adaptive applications multimedia
Transport layer	congestion/flow control quality of service
Network layer	addressing, routing device location hand-over
Data link layer	authentication media access/control multiplexing encryption
Physical layer	modulation interference attenuation frequency

RMSF - OBJECTIVES

- To understand the fundamentals of wireless communications;
- To understand the main techniques used to overcome the difficulties imposed by the wireless medium;
- To learn how the main wireless communication standards integrate those techniques;
- To understand the architecture and design principles of wireless communication systems;
- To understand how the performance of a wireless communication system can be estimated from a practical point of view.

RMSF - TOC

- Principles of Wireless Communications
  - Transmission Fundamentals
  - The Wireless Channel
  - Digital Signal Modulation
  - Spread Spectrum and OFDM
  - Medium Access Techniques
  - CDMA, OFDMA
- Local/Personal Area Networks
  - IEEE 802.11 (WiFi)
  - IEEE 802.15.1 (Bluetooth)
- Wireless and Mobile Internet
  - IP Networking
  - Mobile IP
  - Ad-hoc Networks
- Internet of Things
  - CoAP, MQTT
  - ZigBee
  - LPWAN: LoRaWAN, SigFox, NB-IoT
- Mobile Technologies
  - Terrestrial: 2G, 3G, LTE, LTE-Advanced
  - Satellite

PLANNED INVITED TALKS

- MEO, NOS, Vodafone, Narrownet/SigFox ?