
# Introduction to Wireless and Mobile Networking

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Adapted from Prof. Sunghyun Choi's slides

# Syllabus

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course No. | 430.752B | Lecture No. | 001 | Course Title (Subtitle) | Wireless Networking | Credit | 3 |

| | | | | |
|---|---|---|---|---|
| Representative Instructor | Name | Kyunghan Lee (Associate Professor) | Homepage | https://nxc.snu.ac.kr |
| | E-mail | kyunghanlee@snu.ac.kr | Phone No. | 02-880-1672 |
| | Interview Time/Place : Tue/Thu 11:00am - 12:00pm, Building 301, Room 1006 | | | |

| | |
|---|---|
| Prerequisite | |
| * 1.Purpose of Course | In this course, we will learn and discuss various wireless and mobile networking topics over popular wireless access network standards including 802.11 (WLAN), LTE, and 5G. Such topics will cover conventional approaches as well as state-of-the-art approaches related to major technical issues characterizing the capability and the efficiency of link layer, network layer, and transport layer protocols for wireless and mobile networking. |
| * 2.Materials and Reference | We will mainly use presentation slides and recent research papers for the lectures.<br>Reference<br>* Stefania Sesia, Issam Toufik, Matthew Baker, LTE, The UMTS Long Term Evolution: From Theory to Practice, 2nd Ed., Wiley, 2011.<br>* Bernhard H. Walke, Stefan Mangold, Lars Berlemann, IEEE 802 Wireless Systems: Protocols, Multi-Hop, Performance and Spectrum Coexistence, 1st Ed., Wiley, 2007.<br>* James F. Kurose, Keith W. Ross, Computer Networking, 7th Ed., Pearson, 2016. |

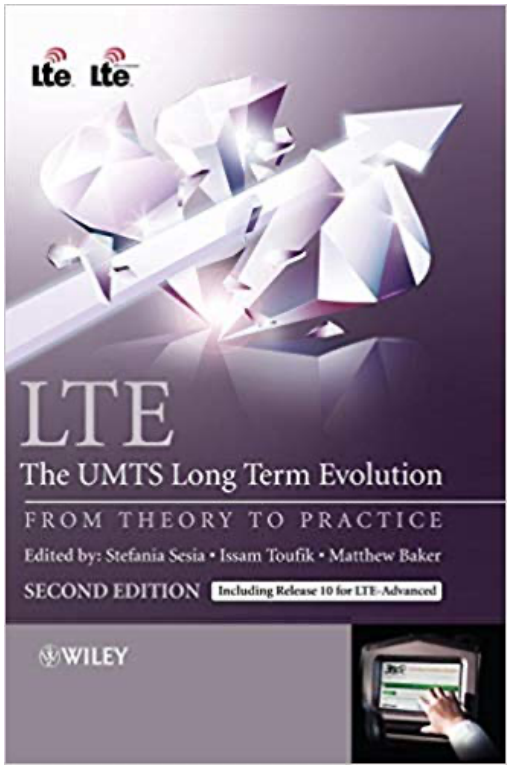
| * 3.Evaluation Method | Attendance | Task | Medium | Final | Random Evaluation | Attitude | Other | Total |
|---|---|---|---|---|---|---|---|---|
| | 10 | 35 | 0 | 40 | 10 | 5 | 0 | 0 |
| | Attendance Policy : | Students who are absent for over 1/3 of the class will receive a grade of 'F' or 'U' for the course. (Exceptions can be made when the cause of absence is deemed unavoidable by the course instructor.) | | | | | | |
| | Remark of Others : | | | | | | | |

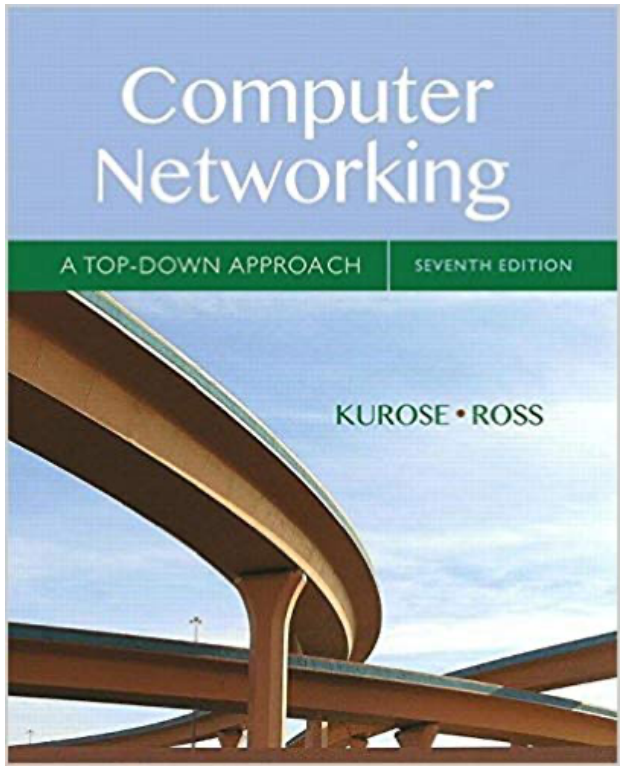
# Syllabus

| | | |
|---|---|---|
| * 4.Lecture Plan | | 3/17 → Week1. Part I. Preliminaries: Introduction to wireless/mobile networking (ONLINE)<br>Week2. Part I. Preliminaries: Performance measures and application performance (ONLINE)<br>3/31 → Week3. Part I. Preliminaries: Wireless access channels<br>Week4. Part I. Preliminaries: Technical issues in the link layer and wireless MAC<br>Week5. Part I. Preliminaries: Technical issues in the network layer and wireless proxy<br>Week6. Part I. Preliminaries: Technical issues in the transport layer and wireless TCP/UDP<br>Week7. Part II. IEEE 802.11 WLANs: Introduction to WiFi networks and their PHY layers<br>Week8. Part II. IEEE 802.11 WLANs: MAC protocols<br>Week9. Part II. IEEE 802.11 WLANs: Recent advances in WiFi networks<br>Week10. Part III. 3GPP LTE/5G networks: Introduction to LTE/5G<br>Week11. Part III. 3GPP LTE/5G networks: RRC/RLC/MAC/Cellular transport protocols<br>Week12. Part IV. Bluetooth/WPAN<br>Week13. Part V. State-of-the-art approaches I<br>Week14. Part V. State-of-the-art approaches II (mainly on AI-based approaches)<br>* The planned contents may vary in order to reflect the most recent research trends. |
| 5.References to Course Registration | | This course is taught in English.<br>Tasks, quizzes, and evaluations may include paper review, presentation, and writing. |
| 6. Support Services for Students with Disabilities<br><br>※ You can modify these default contents. | For Lectures | ○ Physical Disability: Make textbooks (digital textbook), Allow note takers and assistants<br>○ Health Impairment: Excuse absence due to health problems, Allow note takers |
| | For Assignments & Evaluations | |
| | Others | Students who take this course can get appropriate level of support service including the support listed above depending on the students' individual characteristics and needs through consultation with professors and the Support Center for Students with Disabilities. If you have any questions concerning support service for students with disabilities you can Support Center for Students with Disabilities (02-880-8787). |

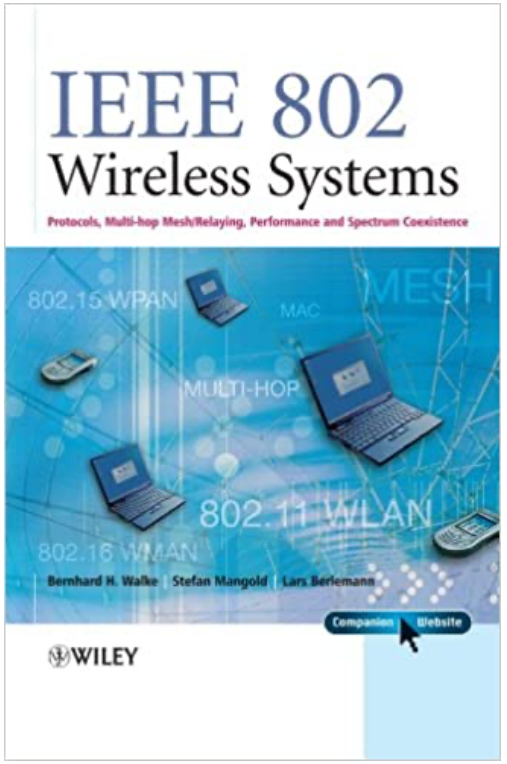
# Main References

LTE from theory to practice

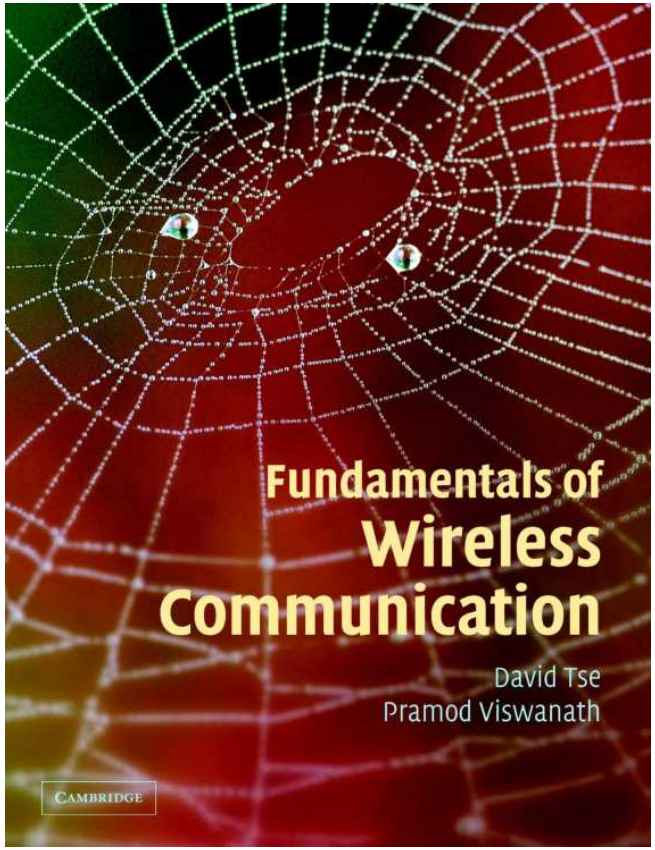



IEEE 802 Wireless Systems



# Fundamentals




Fundamentals of Wireless Communication
David Tse and Pramod Viswanath
Cambridge University Press, 2005

Quiz #1 (03/31) - up to 3 questions

1. Introduction PDF
2. The wireless channel PDF
3. Point-to-point communication: detection, diversity and channel uncertainty PDF

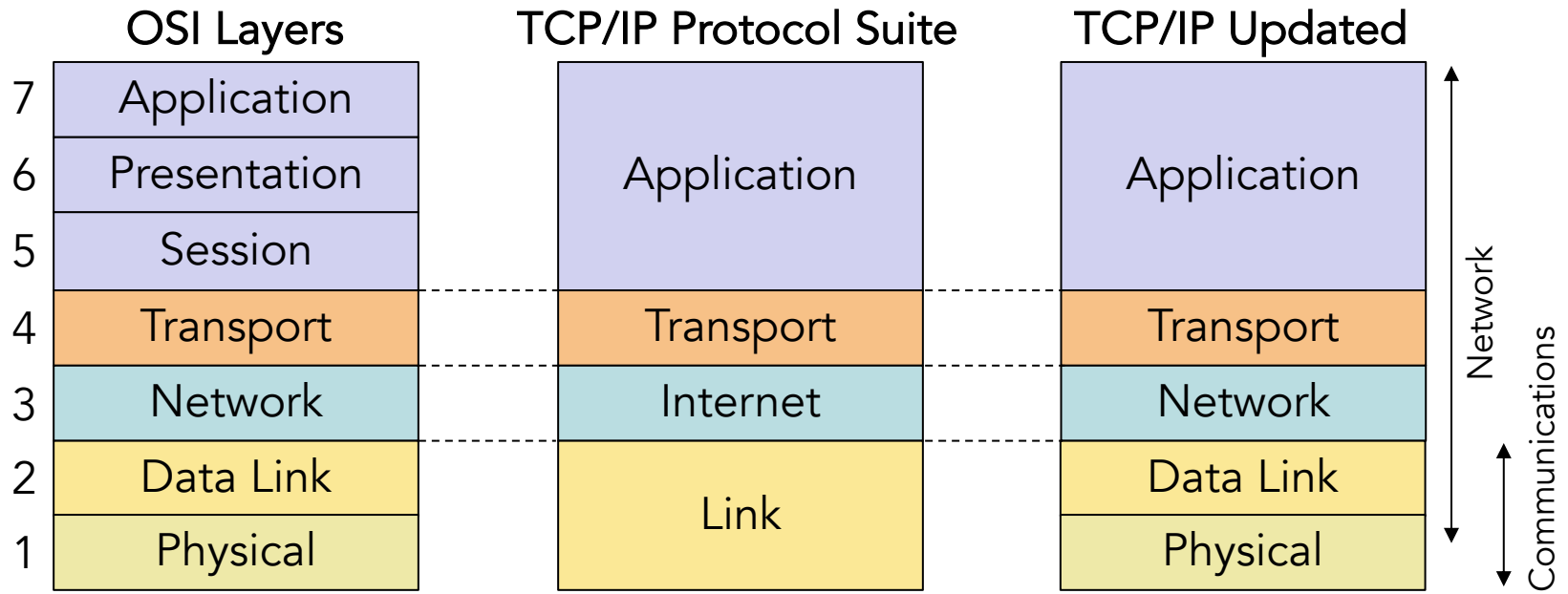
Quiz #2 (04/14) - up to 3 questions

4. Cellular systems: multiple access and interference management PDF
5. Capacity of wireless channels PDF

[BOOK] Fundamentals of wireless communication, D Tse, P Viswanath - 2005 - books.google.com
The past decade has seen many advances in physical layer wireless communication theory and their implementation in wireless systems. This textbook takes a unified view of the fundamentals of wireless communication and explains the web of concepts underpinning …
Cited by 11262 Related articles All 30 versions

# Recall: Layered Network Architecture

- Data link (including MAC) and Physical (PHY) are very system dependent (e.g., WLAN, LTE, 5G)
- Many existing application, transport, and networking layer protocols are developed for wireline, but can be reused for wireless. However …



# Typical Research Questions

- What's new?
  - → Observation paper
- What should we do?
  - → Positioning paper
- How do we implement that?
  - → System paper (placing/mixing dist. functions)
- How much can we improve (in reality)?
  - → (Extensive) Measurement paper
- Is it the best or Is it better (in theory)?
  - → Analysis/Theory paper

Communications theory
(analysis over hardware)
(theory over physics)

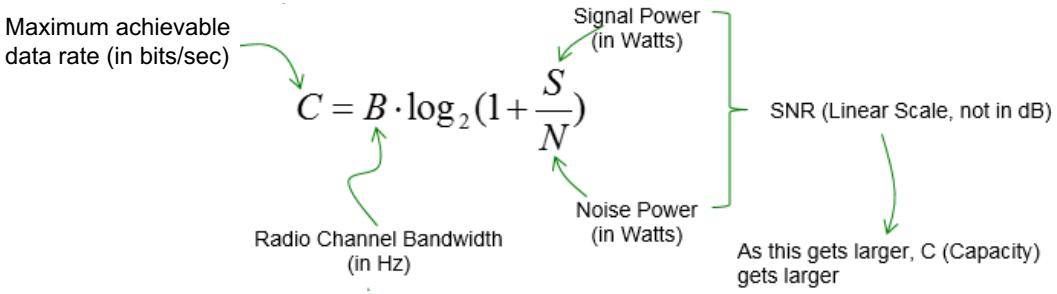
Vs.

Network systems
(mostly software)

Network theory
(analysis over software)

# Wireless vs. Wired

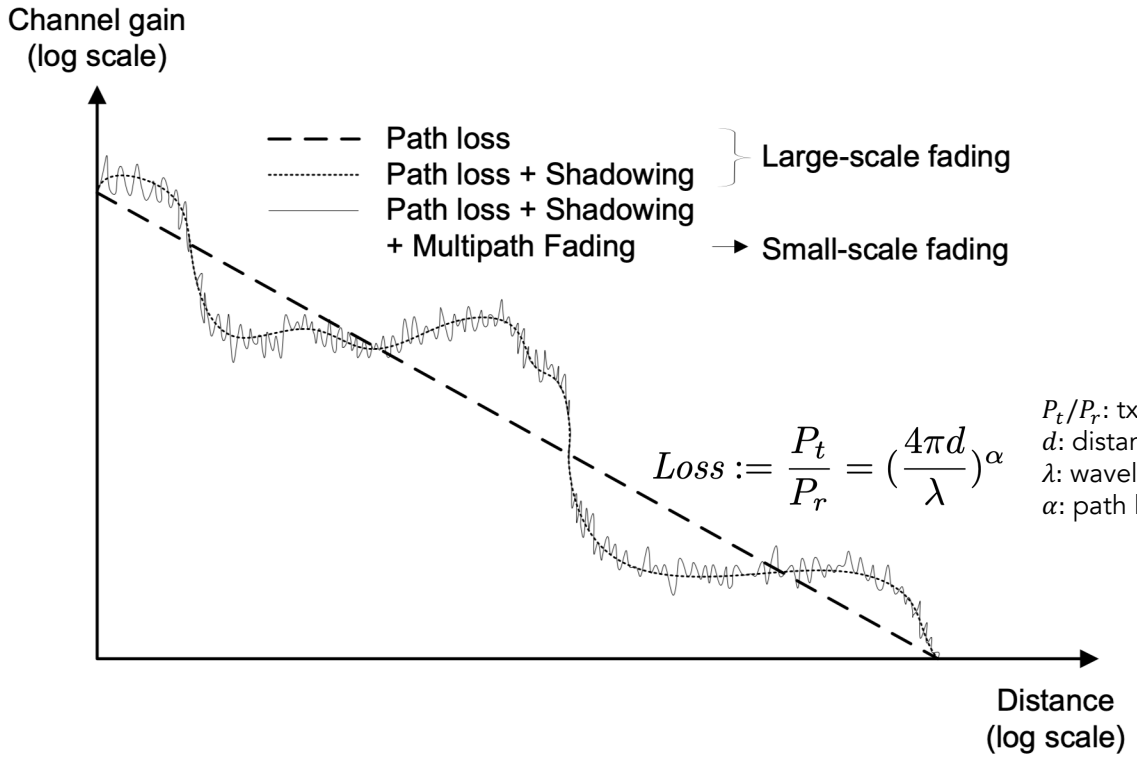
- Scarce resources, i.e., bandwidth
  - 1 Gbps WLAN vs. 1 Gbps LAN




- Less-reliable communication
  - Fading, shadowing, background noise
  - Interferences – inter-symbol interference (ISI), inter-cell interference, interference from other systems
- User mobility
  - Handoff, location management
  - Channel reliability affected by Doppler shift (coherence time)

# Recall: Wireless Channel Gain

- **Path loss:** signal attenuation as it propagates through space
- **Shadowing:** additional signal attenuation caused by blocking objects (walls, buildings) existing between transmitter and receiver
- **Multi-path fading:** constructive and destructive additions of multiple propagation paths



# Wireless vs. Wired

- Time-varying environment
  - Time-varying channel and user mobility
  - Time-varying interferers
  - Location-dependent errors
- Broadcast nature of channel
  - Multiple access for sharing the medium
- Less-secure environment
  - Due mainly to the broadcast nature of the wireless

# Wireless vs. Wired

- Wireless ≠ mobile !

- Wireless node can be static and fixed
  - e.g., Fixed wireless local loop (WLL) or IEEE 802.16 Broadband wireless access (BWA)

- Mobile node can use a wireline networking
  - e.g., laptop with Ethernet link

- Different techniques used to tackle either of them!

# Wireless-aware Protocols

- Application layer
  - Adaptive application, device-dependent, location-dependent, ...
- Transport layer – TCP
  - Packet drops due to channel errors and user mobility are interpreted to be due to the network congestion
- Network layer - IP
  - Different from wireline due to user mobility and broadcast nature of wireless link
  - Mobile IP, ad hoc routing, ...

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## Wireless-agnostic Protocols (popular these days)

- Same application, Same TCP, Same IP
  - How can it be possible?

# Adaptive and Cross-layer Approach

- Wireless environment is time-varying, so the network protocols need to be adaptive
  - MAC with adaptive algorithms for link adaptation, transmit power control, ...
  - Adaptive application using adaptive video codec, adaptive voice codec, ...

- The optimal usage of the scarce and time-varying wireless network can be done via cross-layer design and optimization!

# Wireless & Mobile Networks (WMN)

- Nomadic systems
  - Communications is typically done while the node is stationary
  - WLAN, WPAN
- Mobile systems
  - Communications can be done while the node is moving fast
  - 3G/4G cellular systems
- Nomadic system can provide faster link!

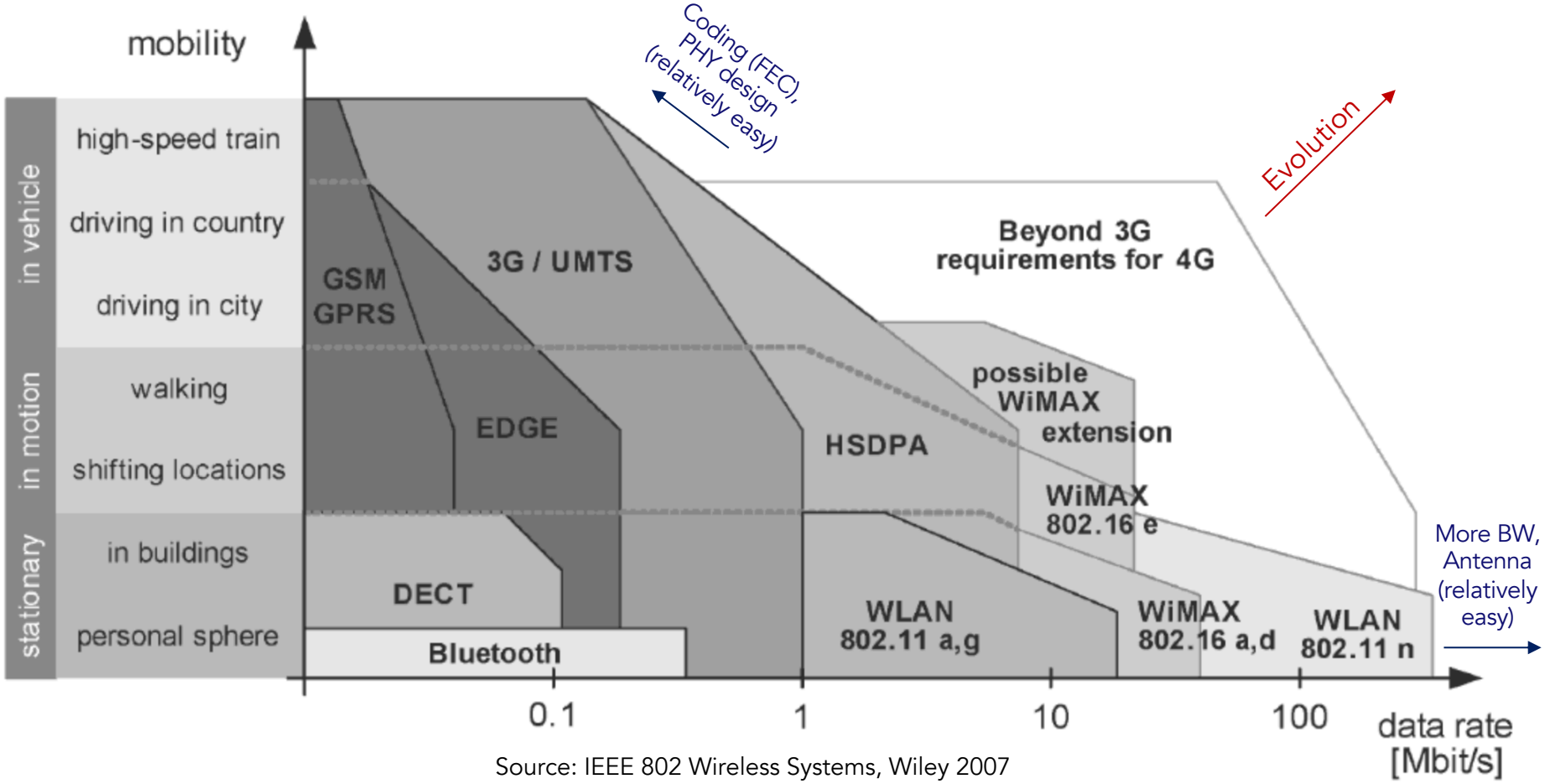
# WMN: Handoff and Mobility Management

- Network and MAC layers related
  - By its nature, a cross-layer design is needed
- Handoff within and across wireless systems
  - Handoff within cellular (e.g., LTE) systems
  - Handoff between WLAN and LTE systems
- Location tracking
  - For paging, location-dependent service, ...

# WMN: Infrastructure vs. Ad hoc

- Infrastructure-based wireless networks
  - An access point (AP) or base station (BS) as an interface between wireless and (wireline) backbone
  - Star topology (in a cell), handoff support
  - Requires cell planning (with frequency reuse)
  - Cellular systems, typical 802.11 WLANs with APs, ...
- Ad hoc networks
  - Wireless multi-hop transmission
  - Peer-to-peer topology
  - 802.11 ad hoc mode, Bluetooth, ...
- Wireless mesh networks
  - Network for wireless infrastructure

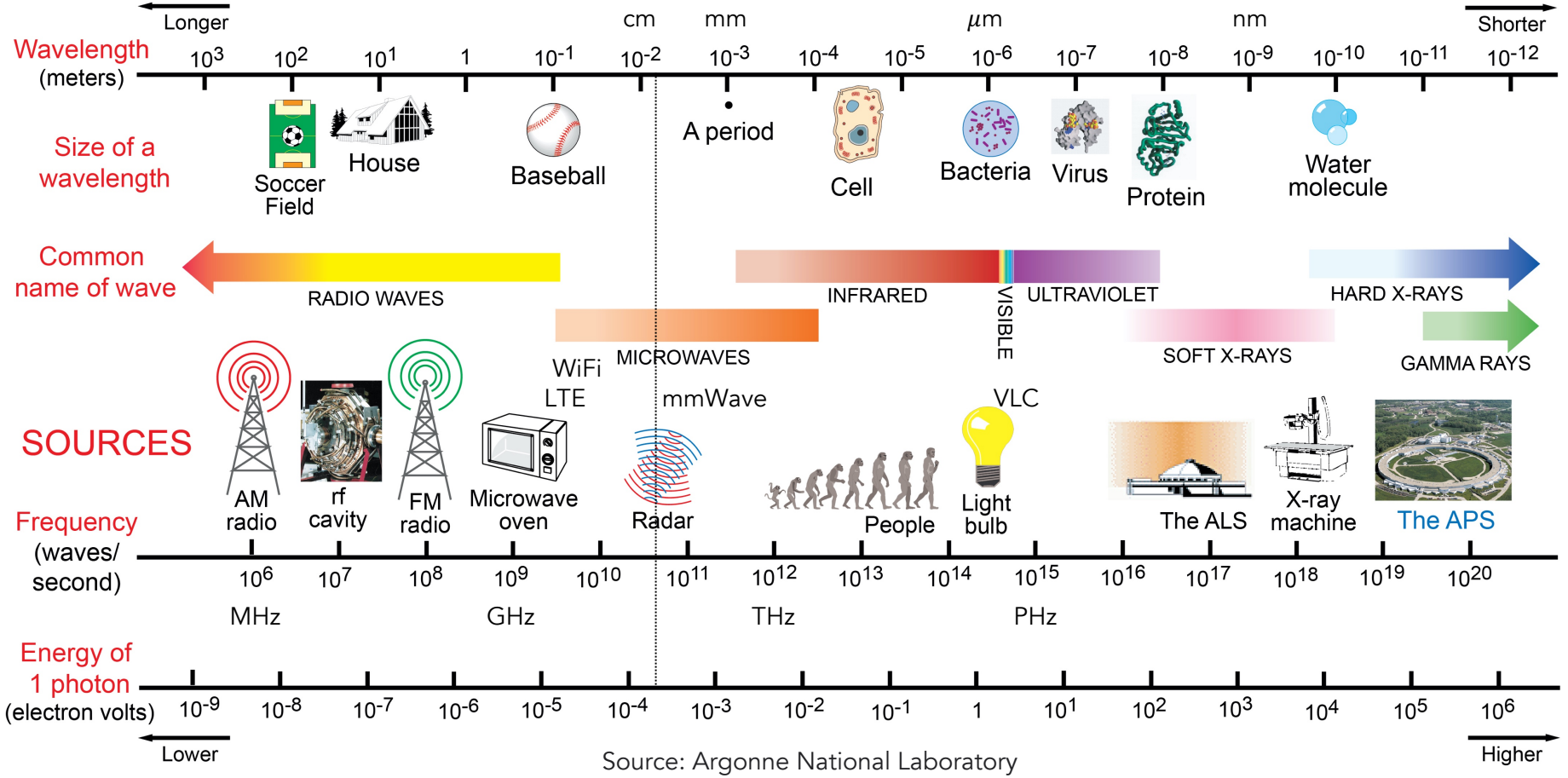
# WMN: Mobility vs. Data Rate




Source: IEEE 802 Wireless Systems, Wiley 2007

# Electromagnetic Spectrum

| Frequency Bands | | Frequency Range |
|---|---|---|
| VLF | very low frequency | 3 kHz - 30 kHz |
| LF | low frequency | 30 kHz - 300 kHz |
| MF | medium frequency | 300 kHz - 3 MHz |
| HF | high frequency | 3 MHz - 30 MHz |
| VHF | very high frequency | 30 MHz - 300 MHz |
| UHF | ultra high frequency | 300 MHz - 3 GHz |
| SHF | super high frequency | 3 GHz - 30 GHz |
| EHF | extremely high frequency | 30 GHz - 300 GHz |

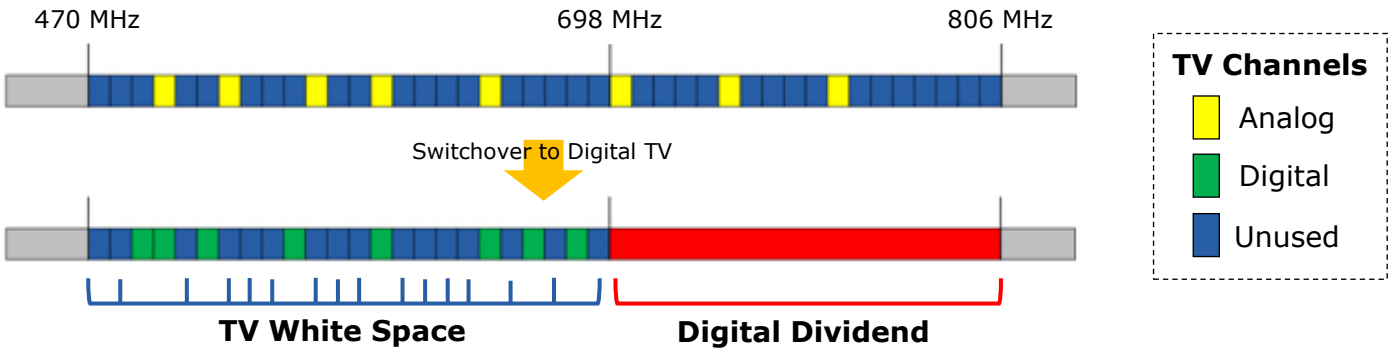



Source: Argonne National Laboratory

# Licensed vs. Unlicensed Bands

- Licensed bands
  - Operators get the license by paying money, ...
  - 800 MHz, 1.8 GHz, 2.1 GHz
- Unlicensed bands
  - Used without license as long as the regulatory requirements are met such as maximum transmit power level, spectral mask, etc.
  - 900 MHz, 2.4 GHz, 5 GHz, 60 GHz ISM (industrial, scientific and medical) bands
- Different for different countries

# TV White Space (TVWS)

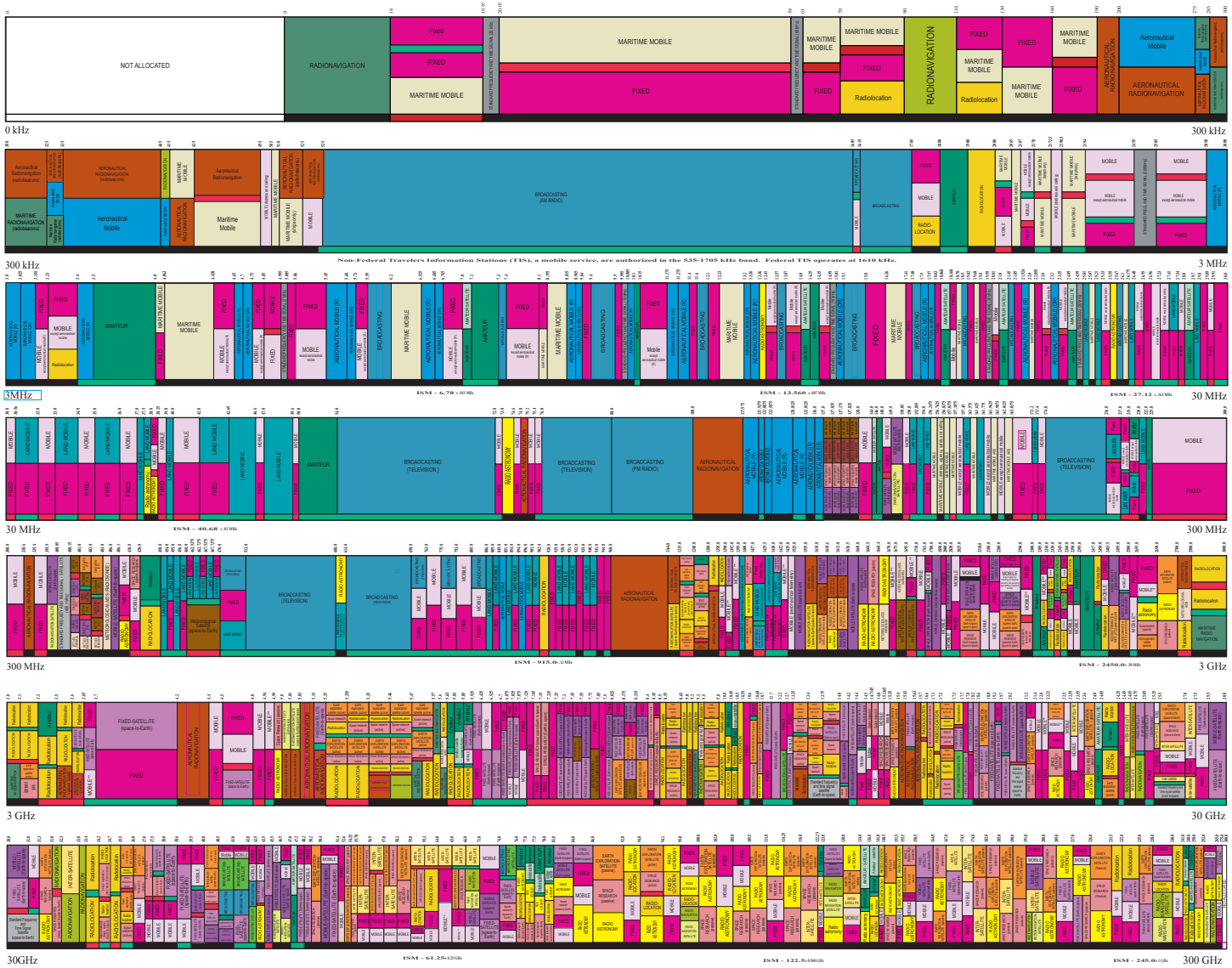



- TV white space (TVWS)
  - Might include 54-72, 76-88, 174-216, and 470-698 MHz
  - Temporally or spatially unused spectrum between active TV channels
  - Available for communication purposes, e.g., Super Wi-Fi, IEEE 802.22, in some countries

- Digital dividend (DD)
  - Became available due to digital TV transition
  - To be allocated for other wireless services

# UNITED STATES FREQUENCY ALLOCATIONS

## THE RADIO SPECTRUM




RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- METEOROLOGICAL
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

- FEDERAL EXCLUSIVE
- FEDERAL/NON-FEDERAL SHARED
- NON-FEDERAL EXCLUSIVE

ALLOCATION USAGE DESIGNATION

| SERVICE | EXAMPLE | DESCRIPTION |
|---|---|---|
| Primary | FIXED | Capital Letters |
| Secondary | Mobile | 1st Capital with lower case letters |

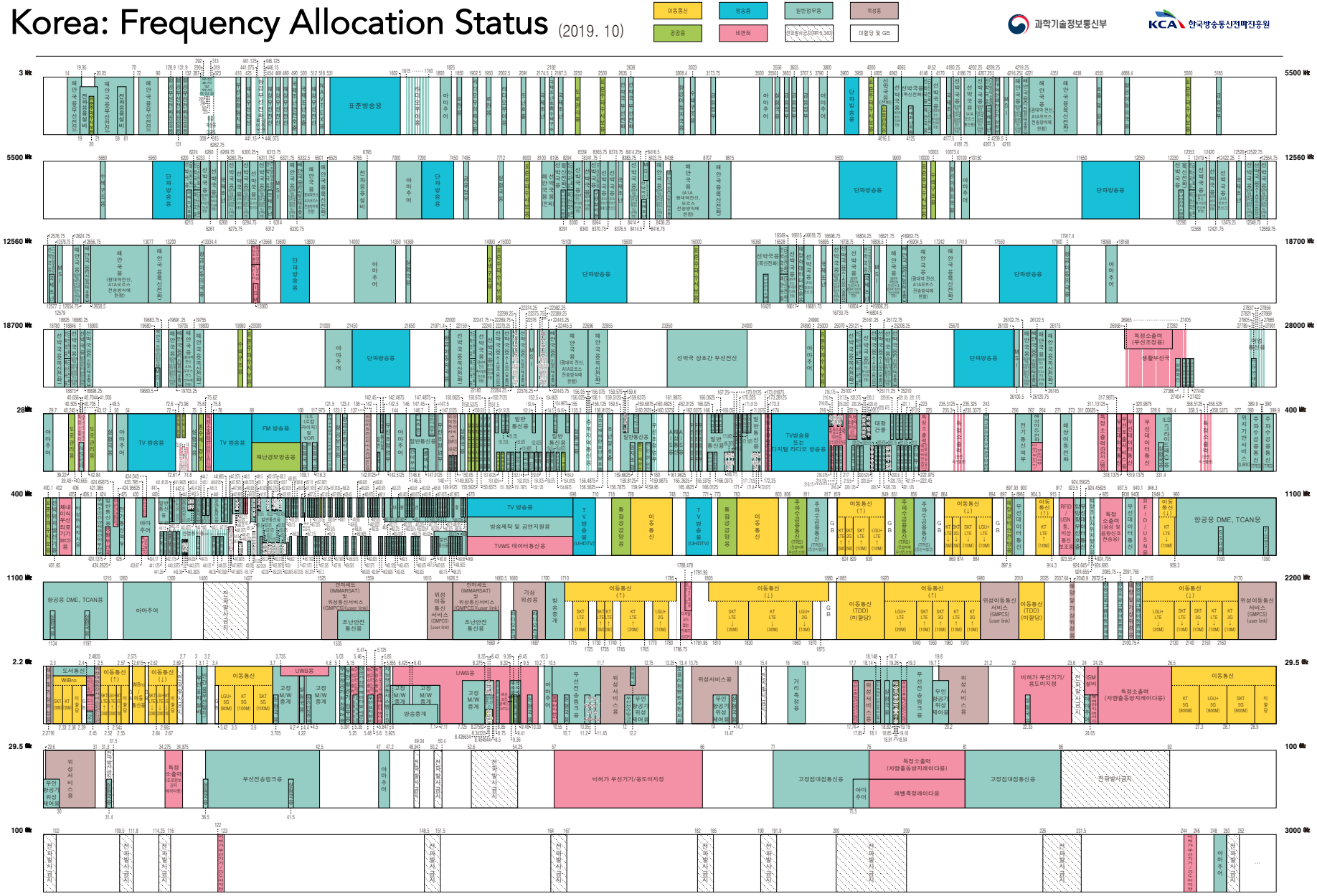
This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it may not completely reflect all aspects, i.e. footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

**U.S. DEPARTMENT OF COMMERCE**
**National Telecommunications and Information Administration**
Office of Spectrum Management

JANUARY 2016

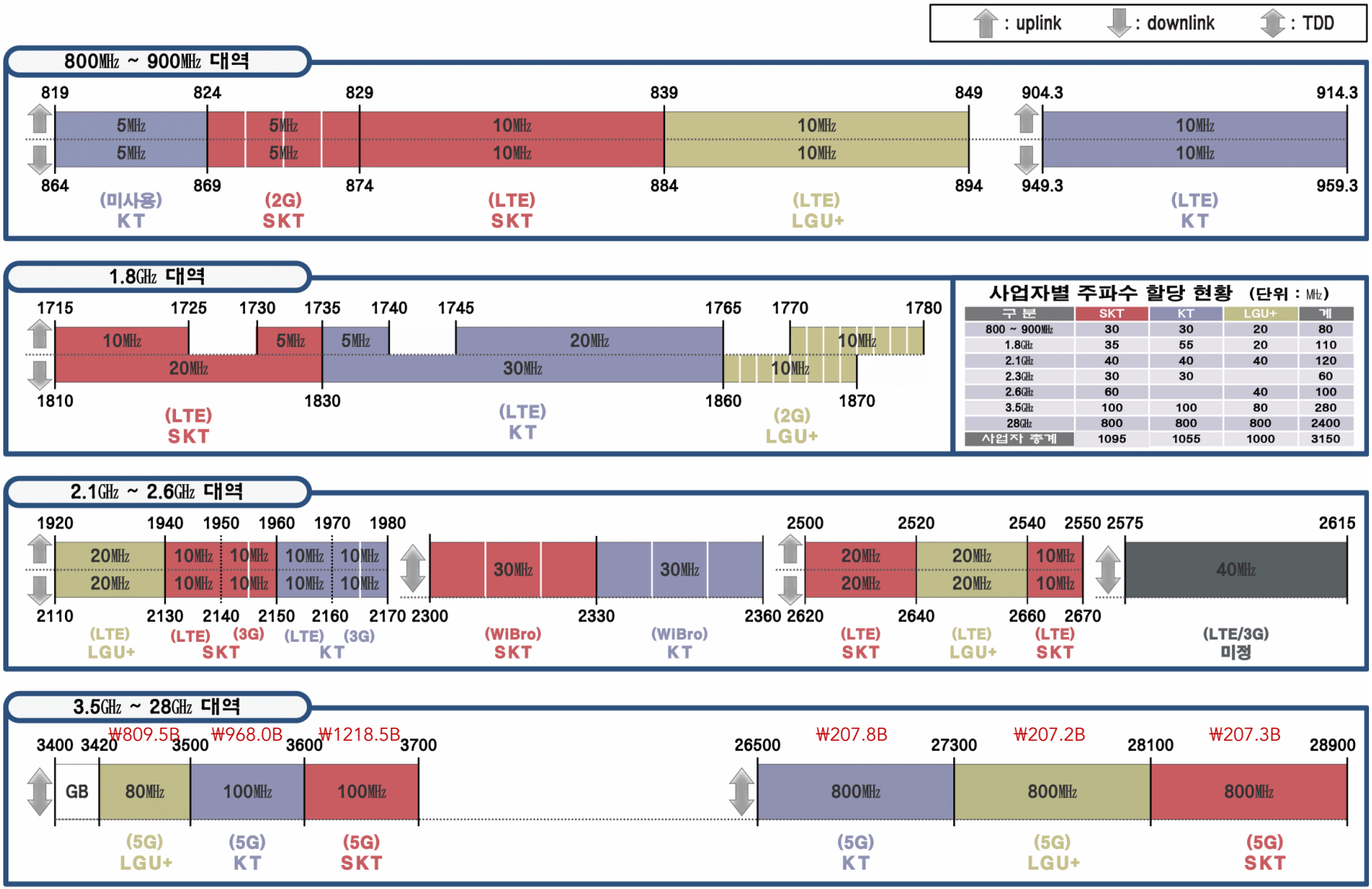
(2016.10)

# Korea: Frequency Allocation Status (2019. 10)



# Allocated Spectrum to Korean MNOs (2018. 06)

과학기술정보통신부 KCA 한국방송통신전파진흥원




사업자별 주파수 할당 현황 (단위 : ㎒)

| 구 분 | SKT | KT | LGU+ | 계 |
|---|---|---|---|---|
| 800 ~ 900㎒ | 30 | 30 | 20 | 80 |
| 1.8㎓ | 35 | 55 | 20 | 110 |
| 2.1㎓ | 40 | 40 | 40 | 120 |
| 2.3㎓ | 30 | 30 | | 60 |
| 2.6㎓ | 60 | | 40 | 100 |
| 3.5㎓ | 100 | 100 | 80 | 280 |
| 28㎓ | 800 | 800 | 800 | 2400 |
| 사업자 총계 | 1095 | 1055 | 1000 | 3150 |