Overview of Wireless Networks

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Outlines

- A very brief history of wireless networks
- A classification of wireless networks
- The wireless spectrum
- Standardization

Some milestones in wireless networks history

- 1792 : Chappe semaphore system
- 1896 : Marconi demonstrates wireless telegraph (Nobel prize in 1909 in physics)
- 1930's : First private radio networks (FM) for the Police and the Army
- 1940's : Pre-cellular Mobile radio telephone, e.g., half-duplex MTS (Mobile Telphone System), full-duplex Improved MTS (US)
- 1980's : 1G cellular analog system : NTT (Nippon Telegraph and Telephone, Japan), NMT (Nordic Mobile Telephone, Denmark, Finland, Sweden, Norway), AMPS (Advanced Mobile Phone System, US), Radiocom2000 (France)
- 1987 : 2G Groupe Spécial Mobile (GSM)
- 1997 : IEEE 802.11 standard
- 1999 : Bluetooth specification
- 2000 : 3G Universal Mobile Telecommunications System (UMTS)
- 2010 : 4G Long Term Evolution (LTE)
- 2020 : 5G New Radio (NR)

A classification of wireless networks I

Cellular networks :

- Principle : the whole territory is divided into cells of radius few hundred m to several km ; allow continuous service, mobility in communication (handover) and roaming, incl. international roaming ; operated in licensed bands below 6 Ghz
- 2G : digital systems, european standard GSM, 900, 1800, 1900 MHz bands in France ; services : mainly voice and SMS ; F/TDMA access ; GPRS/EDGE : data services over GSM, interconnexion with the Internet
- 3G : UMTS in Europe, cdma2000 in US ; 2100 Mhz band in Europe ; CDMA access ; services : voice, video-conference, SMS, MMS, data, access to Internet
- 4G : LTE ; 2600 MHz band in Europe ; OFDMA access ; data-only network, i.e., voice is not natively supported ; rise of the video
- 5G : 3500 MHz in Europe ; higher bit rates but also able to sustain the growth of Internet of things and vertical markets (vehicular, industry, health, etc)
- Private Mobile Radio (PMR) : cellular networks for public safety, police, mission and business critical communications, e.g., TETRA, TETRAPOL

A classification of wireless networks II

Wireless LANs :

- Principle : provides high data rate communication over a small area (few tens of m in indoor, on a campus, etc) to static or users moving at pedestrian speed ; operated in unlicensed bands (usually the 2.4 Ghz, 5 GHz ISM bands, 60 GHz)
- HIPERLAN : a european ETSI standard with EY-NPMA (Elimination-Yield Non-Preemptive Multiple Access mechanism) a priority based access protocol ; support of quality of service and multi-hop communications ; no commercial implementation
- IEEE 802.11b/g/n/ac/ax/ay/ad "WiFi" : using spread spectrum (b), OFDM (g,n,ac), or OFDMA (ax) at physical layer and CSMA/CA at MAC layer ; access point or ad-hoc modes ; WiFi6 (ax) peak rate up to 10 Gbps
- Visible Light Communication "LiFi" : LED visible light is modulated using e.g. on-off keying ; a very high spectrum (about 300 THz) is available ; power consumption is low ; communication only in line of sight

A classification of wireless networks III

Broadband wireless access :

- Principle : provides point-to-multipoint high data rate data communication over a wide distance (several km to tens of km) between fixed stations (an alternative to ADSL) using licensed or unlicensed bands
- "Pre-WiMAX" technologies : LMDS (Local Multipoint Distribution Service), MMDS (Multichannel MDS), Flash-OFDM, 802.20, etc
- IEEE 802.16e/m "WiMAX" : 2.3, 2.5 and 3.5 GHz bands ; OFDMA access ; 802.16m has been seen as a competitor for 4G because it allows mobility but commercially collapsed
- IEEE 802.22 : a "cognitive radio standard" ; deployed in spectrum holes of digital TV (54-862 MHz), so called "TV white spaces" ; many similarities with 802.16 + cognitive radio features
- In practice, broadband wireless access is rather provided by 4G (LTE TDD in France for example).

A classification of wireless networks IV

Wireless Personal Area Networks :

- Principle : provides short range communications (from few m to few tens of m) between devices such as smartphone, PC, printer, sensor, etc. using unlicensed bands ; transceivers should be very low cost, very low energy
- IEEE 802.15.1 “Bluethooth” : 2.4 GHz band, frequency hopping spread spectrum physical layer, high speed and low energy versions
- IEEE 802.15.4, Low rate WPANs : low cost (lower than Bluetooth or WiFi), low rate (from tens to hundreds of kbps), low energy consumption communications for monitoring and control applications ; spread spectrum or ultra-wide-band physical layer ; 6LoWPAN and Zigbee specifications are built upon this standard

A classification of wireless networks V

Low-Power Wide Area Networks :

- Principle : low power (10 year battery life), low data rate (few kbps), long range (typical 10 km) data communications for connecting machines to machines ; an enabler of the Internet of things ; operates in licensed or unlicensed bands
- Sigfox : Ultra Narrow Band modulation ; unlicensed 868 MHz ; an Aloha-like MAC protocol without any need for sensing or synchronization
- LoRa : Chirp Spread Spectrum (a variant of direct sequence spread spectrum) ; unlicensed 868 MHz ; a mix of random and scheduled MAC
- NB-IoT : an extension of LTE networks for IoT

The wireless spectrum I

- Spectrum is a scarce resource in the State public domain
- Different usages :
  - Commercial : mobiles, radio, TV, remote control, independent networks
  - Government : defense (radars, navigation, etc), police, public safety, transports, weather, space, research
- Spectrum allocation has a huge economic, societal and strategic impact !
- The State is responsible for allocating frequencies, coordinating the deployment of radio stations and avoiding as much as possible interferences

The wireless spectrum II

The regulatory process :

- At international level : the general framework is the Radio Regulations (RR) document of the ITU (funded 1985, 191 countries). The world is divided into 3 regions and frequency bands are allocated to services per region. The RR is an international treaty rediscussed every 3 or 4 years in the World Radiocommunication Conference (WRC). France is represented by the Agence Nationale de Fréquences (ANFR).
- At european level : the Electronic Communication Committee (ECC) performs technical studies and conducts harmonization bw european countries ; ETSI produces technical standardization.
- At national level (France) : Tableau National de Répartition des Fréquences (TNRBF) allocates frequency bands between services, administrations (Ministères) and regulatory bodies (ARCEP, CSA) ; ARCEP gives licenses to operators and users.

The wireless spectrum III

Licensed and unlicensed bands :

- Licensed bands : a license is a contract between the regulator and a user of the spectrum (typically an operator) ; there can be license fees (possibly determined with auctions) ; the regulator guarantees a certain quality of service ; it controls the spectrum band. Example : frequency bands for mobile communications are allocated for ≈10 years after an auction and a "beauty contest". Advantage : exclusive use of the spectrum. Drawback : may be very expensive ! (2.8 billions € for 5G in France)
- Unlicensed bands : there is an unlimited access provided that basic rules ("etiquette") are respected, e.g., max transmit power, max transmission range. Example : ISM band 2.4GHz, used by WLANs. Advantage : no authorization required, free. Drawback : you never know who will interfere

The wireless spectrum IV

Challenges in spectrum management :

- Digital dividend : the end of analog TV has freed very interesting frequencies around 400-800 MHz that can be reused for mobile communications. In certain regions TV white spaces could be opportunistically reused
- Refarming : the process of reallocating frequency bands to a different technology. Example : 1800 MHz, a typical band for GSM can now be used for 4G
- Secondary market : an operator can transfer (or sell) the use of a frequency to a third party (under some very specific conditions determined by the regulator) ; it has been adopted for WiMAX licenses in the 3.5 GHz band
- Citizens Broadband Radio Service (CBRS) : A dynamic spectrum access system in the 3.5GHz band (US). A three-tiers system with incumbent access (gvt), priority access (licensed operators) and general authorized access (others – free).

The wireless spectrum V

- Licensed Shared Access : an operator could dynamically authorize the use of certain of its licensed frequencies to a third party
- Cognitive radio : a radio that can dynamically detect spectrum holes and and opportunistically use these holes for its own needs without disturbing primary users
- 5G spectrum : WRC19 (Nov. 2019) : identification of mm wave frequencies (26-40-47 GHz) where huge spectrum are available (at least 15 GHz). Next WRC in 2023.

Standardization I

3rd Generation Partnership Project (3GPP) standardization :

- `www.3gpp.org`
- 3GPP unites 7 standardization bodies from US, China, Japan, Europe, South Korea, India, incl. ETSI
- It provides cellular networks specifications including Radio Access Network (RAN), Core Network (CN), terminal and service aspects
- Specifications are organized in Releases

Table – 3GPP releases

Releases	Technologies	Date
R99-R4	UMTS	2000-2001
R5-R8	HSPA	2002-2008
R8-R9	LTE	2008-2009
R10-R12	LTE-Advanced	2010-2016
R13-R14	LTE-Advanced Pro	2016-2017
R15	5G New Radio	Dec. 2017

Standardization II

IEEE standardization :

- `standards.ieee.org`
- IEEE is not a governmental or recognized international standard body
- IEEE 802 is the group responsible for LANs and MANs
- IEEE standardizes physical and MAC/RLC layers ; industry fora like "WiFi", "Bluetooth", or "WiMAX" are responsible for architectures and higher layers design, and inter-operability tests. They produce their own specifications

Table – Some IEEE standards

Standards	Technologies	Forum
802.11	WLAN	WiFi
802.15.1	WPAN	Bluetooth
802.15.4	Low Rate WPAN	Zigbee
802.16	Broadband Wireless Access	WiMAX
802.22	Wireless Regional Area Network	–

Standardization III

IETF standardization in wireless networks

- IETF standardizes higher layer protocols (from layer 3 onwards).
- Mobile IP/IPv6 : a roaming protocol to allow a user to move from one network to another while maintaining a permanent IP address
- MANETs : DSR, AODV, OLSR
- Constrained networking : Internet protocols are extended to sensor networks with Ipv6 over Low Power WPAN (6LoWPAN, IPv6 over 802.15.4), Routing over Low Power and Lossy Networks (ROLL), Constrained Restful Environment (CORE)

Acronyms I

3GPP	Third Generation Partnership Project
ANFR	Agence Nationale des Fréquences
ARCEP	Autorité de régulation des communications électroniques et des postes
AODV	Ad-hoc On Demand Distance Vector
CBRS	Citizens Broadband Radio Service
CDMA	Code Division Multiple Access
CN	Core Network
CORE	Constrained Restful Environment
CSA	Conseil Supérieur de l'Audiovisuel
CSMA/CA	Carrier Sense Multiple Acces/Collision Avoidance
DCS	Digital Cellular System
DECT	Digital Enhanced Cordless Telecommunications
DSR	Dynamic Source Routing
EDGE	Enhanced Data Rates for GSM
EY-NPMA	Elimination-Yield Non-Preemptive Multiple Access
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GPRS	General Packet Radio Service
GSM	Groupe Spécial Mobile
HSPA	High Speed Packet Access
IoT	Internet of Things
IMT	International Mobile Telecommunications
ISM	Industrial Scientific Medical
LAN	Local Area Network
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution
MAC	Medium Access Control

Acronyms II

MAN	Metropolitan Area Network
MMS	Multimedia Message Service
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
OLSR	Optimized Link State Routing
PMR	Private Mobile Radio
RAN	Radio Access Network
ROLL	Routing over Low Power and Lossy Networks
SMS	Short Message Service
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WRC	World Radiocommunications Conference