Overview of Wireless Networks

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Objectives

- Have a broad overview of existing wireless networks
- Have a classification of wireless networks
- Understand the main challenges in spectrum management
- Have a broad overview of the standardization players

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

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
- 4G : LTE ; 2600 MHz band in Europe ; OFDMA access ; data-only network, i.e., voice is not natively supported
- 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 data 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 and/or 5 GHz ISM bands)
- 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 "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
- 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

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 mixe 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 !
- 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

Today's 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

The wireless spectrum V

- Licensed Shared Access : an operator could dynamically authorize the use of certain of his 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 : WRC15 has started identifying frequency bands ; WRC19 (end of Nov. 2019) : identification of mm wave frequencies (above 24 GHz up to 66 GHz) where huge spectrum may be available

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)