Mobile System Connectivity

CSE 3203
Overview of Mobile Systems

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Fall 2018
Overview

• Connectivity is the foundation of a great mobile experience

• The connectivity layer provides the basic connection infrastructure for mobile systems; this includes:
  – Mobile operators/carriers
  – Connections and networks (standards)
  – Devices for connections
Operators/Carriers

A mobile network operator or MNO, also known as a carrier, is a provider of wireless communications services that owns or controls all the elements necessary to sell and deliver services to an end user:
- own or control access to a radio spectrum license from a regulatory or government entity
- own or control the elements of the network infrastructure necessary to provide services to subscribers over the licensed spectrum.

https://en.wikipedia.org/wiki/Mobile_network_operator

Major responsibilities
- Create and maintain the mobile infrastructure: towers, satellites, cables, access points, etc.
- Provide connection services and Internet/data services
Top Global Mobile Operators

- Top operators in the world by subscriptions

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Country</th>
<th>Total subscriptions (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China Mobile</td>
<td>China</td>
<td>901.9 (May 2018)</td>
</tr>
<tr>
<td>2</td>
<td>Vodafone</td>
<td>UK</td>
<td>535.8 (March 2018)</td>
</tr>
<tr>
<td>3</td>
<td>Airtel</td>
<td>India</td>
<td>450.7 (March 2018)</td>
</tr>
<tr>
<td>4</td>
<td>China Unicom</td>
<td>China</td>
<td>297.0 (April 2018)</td>
</tr>
<tr>
<td>5</td>
<td>América Móvil</td>
<td>Mexico</td>
<td>279.1 (March 2018)</td>
</tr>
<tr>
<td>6</td>
<td>China Telecom</td>
<td>China</td>
<td>276.1 (May 2018)</td>
</tr>
<tr>
<td>7</td>
<td>Telefónica</td>
<td>Spain</td>
<td>271.9 (June 2018)</td>
</tr>
</tbody>
</table>

- Also see the top ten by market value
  - [https://www.investopedia.com/articles/markets/030216/worlds-top-10-telecommunications-companies.asp](https://www.investopedia.com/articles/markets/030216/worlds-top-10-telecommunications-companies.asp)
The Big 4 in US

By subscriptions
https://en.wikipedia.org/wiki/List_of_United_States_wireless_communications_service_providers
- Verizon Wireless: 152.7 million (Q2 2018)
- AT&T Mobility: 147.3 million (Q2 2018)
- T-Mobile US: 75.6 million (Q2 2018)*
- Sprint Corporation: 53.7 million (Q2 2018)*

* T-Mobile and Spring proposed a merger in Jun 2018
https://www.digitaltrends.com/mobile/t-mobile-sprint-merger/

Market share:
Mobile Virtual Network Operator

- A mobile virtual network operator (MVNO), virtual network operator (VNO), or mobile other licensed operator (MOLO), is a wireless communications services provider that does not own the wireless network infrastructure (and mobile spectrum license) over which it provides services to its customers.
  - [https://en.wikipedia.org/wiki/Mobile_virtual_network_operator](https://en.wikipedia.org/wiki/Mobile_virtual_network_operator)

- An MVNO enters into a business agreement with a mobile network operator to obtain bulk access to network services at wholesale rates, then sets retail prices independently. An MVNO may use its own customer service, billing support systems, marketing, and sales personnel, or it could employ the services of a mobile virtual network enabler (MVNE).

- MVNOs work independently of mobile network operators (MNOs) and can set their own pricing structure subject to the rates they've agreed to pay MNOs. MVNOs do not own any core mobile network-related infrastructure such as radio access networks or mobile switching centers. MVNOs appear as roaming partners of overseas networks if they own their own home location register. Certain MVNOs also run their own billing and customer care solutions called business support systems.

- Mobile virtual network operators (MVNOs) in the United States lease wireless telephone and data service from major carriers such as AT&T Mobility, Sprint Corporation, T-Mobile US, and Verizon Wireless, as well as regional carrier United States Cellular Corporation for resale. The largest operator of MVNO's is TracFone Wireless with over 25 million subscribers.

- Notable operators
  - Project Fi [https://www.androidcentral.com/project-fi](https://www.androidcentral.com/project-fi)
  - Metro PCS
MVNO Types

• Branded reseller
  – Sometimes referred to as a "Skinny MVNO", as the reseller almost totally relies on the MNO's facilities. They do not own any network elements, but may own and operate their own customer care, marketing, and sales operations.

• Service Provider
  – Sometimes referred to as a "Light MVNO". The service provider operates its own customer support, marketing, sales and distribution operations, and has the ability to set its tariffs independently from the retail prices set by the MNO.

• Enhanced Service Provider
  – Sometimes referred to as a "Thick MVNO". The MVNO manages a more complete technical implementations with its own infrastructure which allows the MVNO more control over its offerings. These MVNOs have a heavier focus on branding, customer-ownership, and differentiation through added services like data and SIM applications.

• Full MVNO
  – These MVNOs have a network implementation operating essentially the same technology as a mobile network operator. Full MVNOs only lack their own radio networks.

• See
  – [https://en.wikipedia.org/wiki/Mobile_virtual_network_operator#Types](https://en.wikipedia.org/wiki/Mobile_virtual_network_operator#Types)
Goodies


• https://bestmvno.com/mvnos/
Connections

• Connection (data transfer) through air and radio waves

• All radio access technologies have to solve the same problems: to divide the finite RF spectrum among multiple users as efficiently as possible.
Major Connection Types

- **Wide area (mobile broadband)**
  - Cellular networks: GSM, HSPA, LTE: provide direct connection and maintained by mobile operators
  - Wide coverage but lower speed (compared to WiFi)
  - Broadband wireless access [https://en.wikipedia.org/wiki/Mobile_broadband](https://en.wikipedia.org/wiki/Mobile_broadband)
  - Satellite

- **Local area**
  - Wireless LAN, WiFi, 802.11 family of standards
  - Can be set up by private (home or workplace) or public (mall, airport, etc.) providers
  - High speed but limited coverage
  - Mobile hotspot: WiFi + Cellular

- **Wireless near-me or personal area network (WPAN)**
  - Direct P2P connections: Bluetooth, NFC

Cellular Network

- In the case of cellular networks, the data is transmitted through a network of transmitters and receivers.

- A mobile phone network is divided into thousands of overlapping geographic areas, or *cells*. A typical cellular network can be envisioned as a mesh of hexagonal cells,
<table>
<thead>
<tr>
<th>Cellular Network Generations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1G</strong></td>
</tr>
<tr>
<td>Introduced in year</td>
</tr>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>Multiple Address/Access system</td>
</tr>
<tr>
<td>Switching type</td>
</tr>
<tr>
<td>Speed (data rates)</td>
</tr>
<tr>
<td>Special Characteristic</td>
</tr>
<tr>
<td>Features</td>
</tr>
<tr>
<td>Supports</td>
</tr>
</tbody>
</table>

https://www.qualcomm.com/documents/evolution-mobile-technologies-1g-2g-3g-4g-lte
1G to 4G Comparison

**Mobile 1G**
AMPS, NMT, TACS

**Mobile 2G**
D-AMPS, GSM/GPRS, cdmaOne

**Mobile 3G**
CDMA2000/EV-DO, WCDMA/HSPA+, TD-SCDMA

**Mobile 4G LTE**
LTE, LTE Advanced

<table>
<thead>
<tr>
<th>1G to 4G</th>
<th>1G established seamless mobile connectivity introducing mobile voice services</th>
</tr>
</thead>
<tbody>
<tr>
<td>2G to 4G</td>
<td>2G digital wireless technologies increased voice capacity delivering mobile to the masses</td>
</tr>
<tr>
<td>3G to 4G</td>
<td>3G optimized mobile for data enabling mobile broadband services, and is evolving for faster and better connectivity</td>
</tr>
<tr>
<td>4G to 4G</td>
<td>4G LTE delivers more capacity for faster and better mobile broadband experiences, and is also expanding in to new frontiers</td>
</tr>
</tbody>
</table>

[https://www.qualcomm.com/documents/evolution-mobile-technologies-1g-2g-3g-4g-lte](https://www.qualcomm.com/documents/evolution-mobile-technologies-1g-2g-3g-4g-lte)
Cellular Generation Market

• Generation of cellular connections

5G

• What is 5G?
  – https://www.youtube.com/watch?v=2DG3pMcNNlw

• 5G is the fifth generation of mobile connection technologies defined by 3GPP (3rd Generation Partnership Project) – the standard body that also overlooked the development of 3G UMTS (including HSPA) and 4G LTE standards.

• Currently under development
  – 5G technology is expected to officially launch across the world by 2020

• https://www.tomsguide.com/us/5g-networking-faq,news-20629.html
Key Technologies and Standards

• GSM (vs. CDMA)
• CDMA (vs. TDMA)
• HSPA+
• LTE

• See more
  – https://www.pcmag.com/encyclopedia/term/55406/cellular-generations
Wireless LAN Access Point

• WiFi
  – Wi-Fi is the name of a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections.
  – Wi-Fi is a trademarked phrase that means IEEE 802.11x family standards.
  – A common misconception is that the term Wi-Fi is short for "wireless fidelity," however this is not the case.
  – [http://www.webopedia.com/TERM/W/Wi_Fi.html](http://www.webopedia.com/TERM/W/Wi_Fi.html)

• Features
  – Limited coverage for home, workplace, business location, etc.
  – High speed
  – Hardware integrated (almost all these days)
802.11x Comparison

• 802.11 Standards Explained

<table>
<thead>
<tr>
<th></th>
<th>802.11 (legacy)</th>
<th>802.11a</th>
<th>802.11b</th>
<th>802.11g</th>
<th>802.11n</th>
<th>802.11ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Speed</td>
<td>1.2 Mbit/s</td>
<td>54 Mbit/s</td>
<td>11 Mbit/s</td>
<td>54 Mbit/s</td>
<td>150 Mbit/s</td>
<td>800 Mbit/s</td>
</tr>
<tr>
<td>MIMO</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>up to 4</td>
<td>up to 8</td>
</tr>
<tr>
<td>Frequency</td>
<td>2.4 GHz</td>
<td>5.8 GHz</td>
<td>2.4 GHz</td>
<td>2.4 GHz</td>
<td>2.4 &amp; 5 GHz</td>
<td>5 GHz</td>
</tr>
</tbody>
</table>

http://www.androidauthority.com/wifi-standards-explained-802-11b-g-n-ac-ad-ah.af-666245/
Mobile Hotspot

• A device that taps into 3G and/or 4G cellular networks, and then wirelessly shares its data connection with other nearby (within 30 feet or so) Wi-Fi-enabled devices.


• Devices

  – https://www.pcmag.com/article2/0,2817,2400503,00.asp
Public Mobile Hotspots

• Operators provide hotspot services
  – http://hotspots.wifi.comcast.com
  – https://www.att.com/maps/wifi/basic.html
  – https://wifispc.com
  – Google Free Wifi hotspot
WPAN

- Wireless Personal Area Network
  - Bluetooth
  - NFC
Bluetooth

- Bluetooth® is a low-power wireless connectivity technology used to connect devices in short distance.

<table>
<thead>
<tr>
<th>Bluetooth version</th>
<th>Maximum speed</th>
<th>Maximum range</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>25 Mbit/s</td>
<td>10 meters (33 ft)</td>
</tr>
<tr>
<td>4.0</td>
<td>25 Mbit/s</td>
<td>60 meters (200 ft)</td>
</tr>
<tr>
<td>5</td>
<td>50 Mbit/s</td>
<td>240 meters (800 ft)</td>
</tr>
</tbody>
</table>

- Typical uses
  - Connecting input/output devices like speaker, headset, mouse, keyboard, controller
  - Sharing data and files

NFC

- NFC stands for Near Field Communication.
  - A way for phones/devices to interact in close proximity - a radius of about 4 cm
  - allows for two-way communication, with both devices involved being able to send and receive information.
  - does not rely on Wi-Fi, 3G, LTE or otherwise, and it doesn't cost anything to use

- Typical usage
  - Send/share short message or photos
  - Share files directly
  - Payment
  - Sensors objects (vs. QR code)
  - Open doors (cars)
  - [https://www.androidpit.com/what-is-nfc](https://www.androidpit.com/what-is-nfc)
# NFC vs. Bluetooth

<table>
<thead>
<tr>
<th>NFC</th>
<th>Bluetooth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>History</strong></td>
<td>2004, initiated by Nokia, Sony, Philips</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>Radio waves; frequency-hopping spread spectrum</td>
</tr>
<tr>
<td><strong>Standards</strong></td>
<td>ISO, ECMA, ETSI</td>
</tr>
<tr>
<td><strong>Users (in %)</strong></td>
<td>200 million</td>
</tr>
<tr>
<td><strong>Communication frequency</strong></td>
<td>13.56 MHz</td>
</tr>
<tr>
<td><strong>Data transfer rate</strong></td>
<td>424 kbits/s</td>
</tr>
<tr>
<td><strong>Power consumption</strong></td>
<td>Very Less</td>
</tr>
<tr>
<td><strong>How it works</strong></td>
<td>No pairing required for data transfer</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td>Tap screen to transfer data (highly intuitive)</td>
</tr>
<tr>
<td><strong>Ease of use</strong></td>
<td>Very easy</td>
</tr>
<tr>
<td><strong>Data exchange over distance</strong></td>
<td>Within 4 cm</td>
</tr>
<tr>
<td><strong>Data transfer ability</strong></td>
<td>Very fast</td>
</tr>
<tr>
<td><strong>Multi-device connectivity</strong></td>
<td>2 Devices at the same time</td>
</tr>
<tr>
<td><strong>Cost-effectiveness</strong></td>
<td>Expensive</td>
</tr>
<tr>
<td><strong>Convenience</strong></td>
<td>High</td>
</tr>
<tr>
<td><strong>Social networking ability</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Payment transaction</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Intermediate; neither high nor low (allows for anti-virus installation)</td>
</tr>
<tr>
<td><strong>Benefited Sectors</strong></td>
<td>Electronics, Healthcare, Transport, Payments, Access Control, etc.</td>
</tr>
</tbody>
</table>

Good Resources

• Qualcomm learning resources
  – https://www.qualcomm.com/wireless-simplified


• FCC Mobile Wireless Competition Reports

• https://whatsag.com