RADFORD UNIVERSITY

Wireless Communication

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Key Reference:
Prof. Jong-Moon Chung's Lecture Notes at Yonsei University

Wireless Communications

- Bluetooth
- Wi-Fi
- Mobile Communications
- LTE
- LTE-Advanced

Wi-Fi

WLAN

- **WLAN (Wireless Local Area Network) is a wireless networking technology that links two or more computing devices using a wireless distribution method within a limited local area**

- **Applications Areas: Home, School, Computer Laboratory, Office Building, etc.**

Wi-Fi

Wi-Fi

- **Wi-Fi (or WiFi) is a WLAN technology that allows electronic devices to network mainly using the ISM radio bands**
  - **2.4 GHz UHF (Ultra High Frequency)**
  - **5 GHz SHF (Super High Frequency)**

Wi-Fi

Wi-Fi Transmission

- 5 GHz offers higher throughput at shorter distances
- 2.4 GHz provides increased coverage and improved solid object penetration
- Beamforming and other multiple antenna technologies like MIMO are used to increase the date rate and QoS

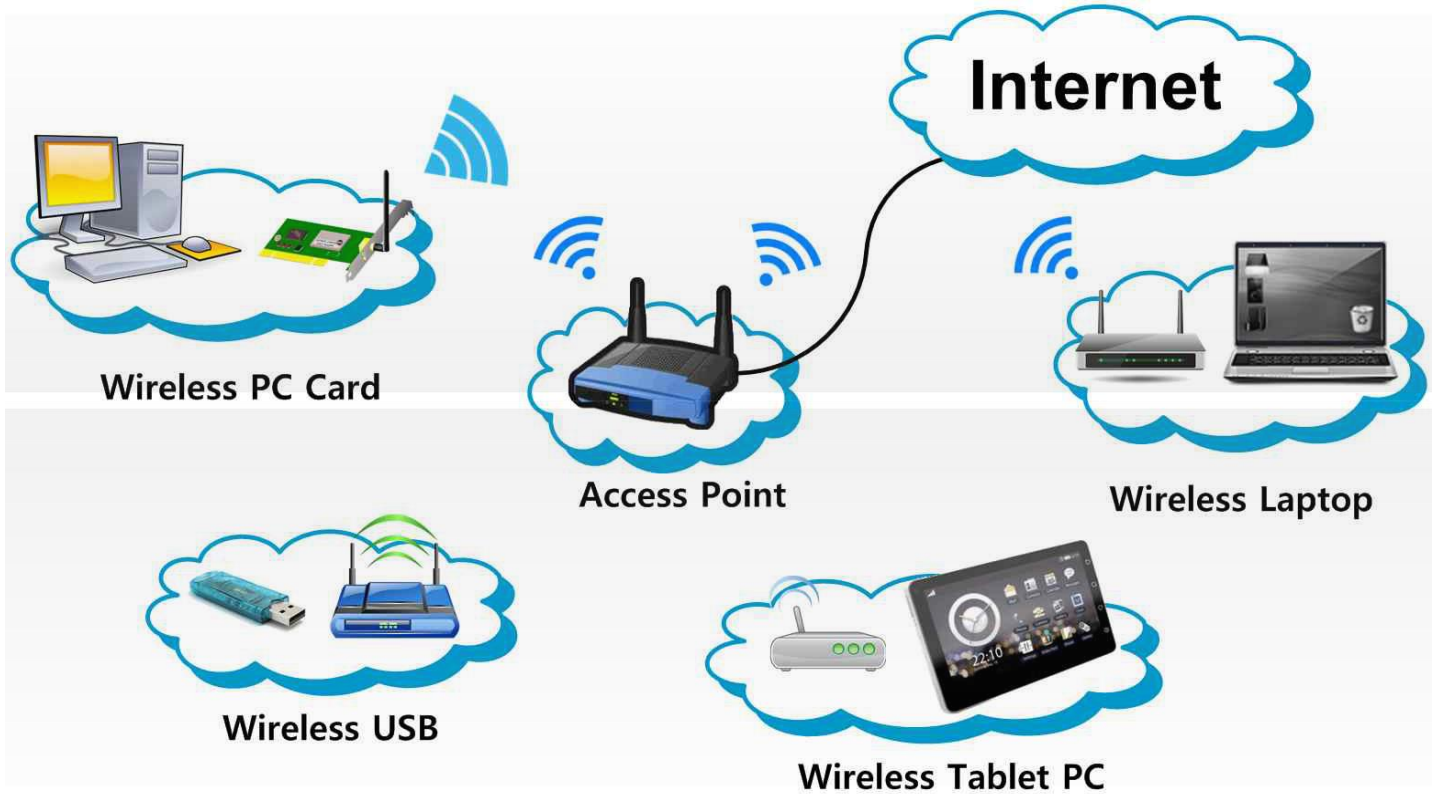
Wi-Fi

Wireless AP (Access Point)

- A device that allows Wi-Fi devices to connect to a wired network
- AP usually connects to a router or may have built in router capabilities

Wi-Fi

Example of an AP network



Wi-Fi

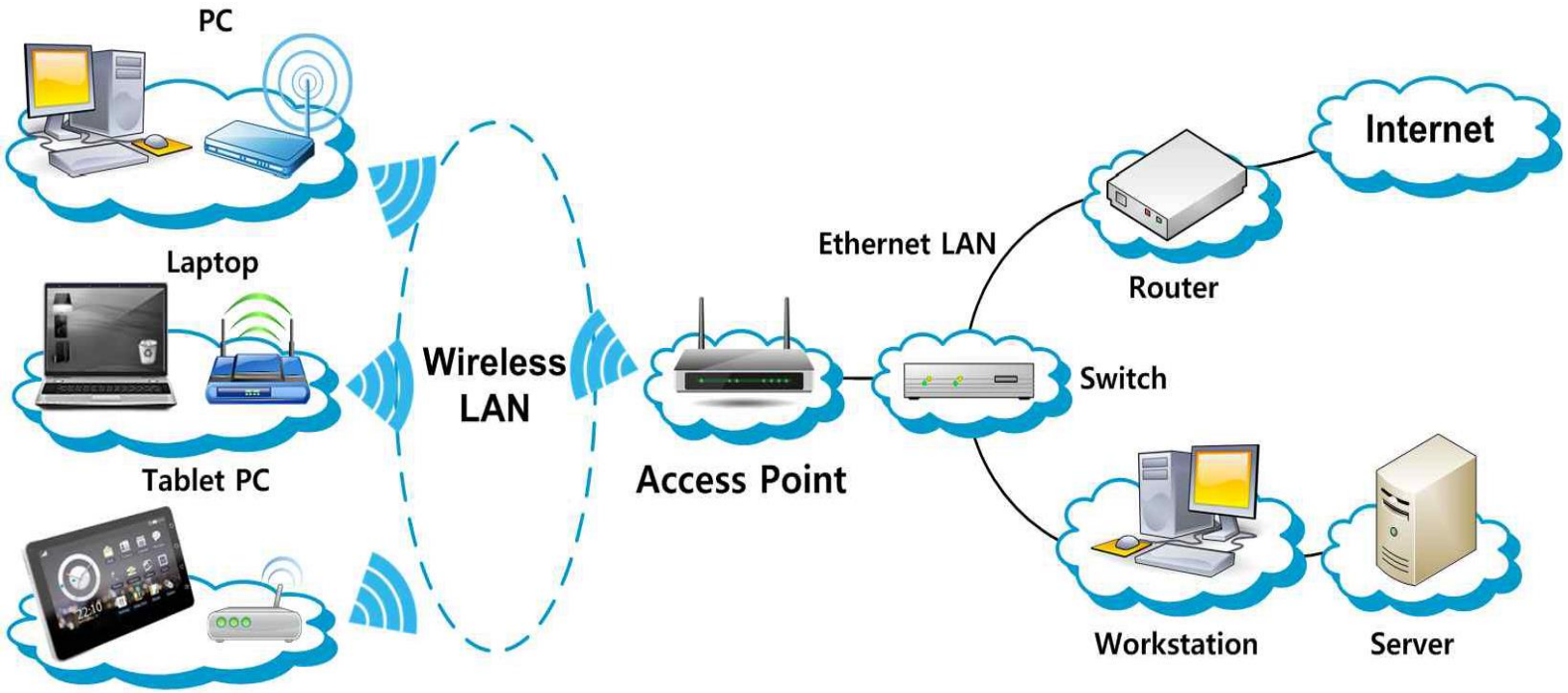
Infrastructure Mode

- In infrastructure mode, Wi-Fi devices can
  - communicate with each other and
  - communicate with a wired network

- BSS (Basic Service Set)
  - In infrastructure mode, commonly one AP is connected by wire to the Internet, and a set of Wi-Fi devices connect to the AP

Wi-Fi

Example of Infrastructure mode



Wi-Fi

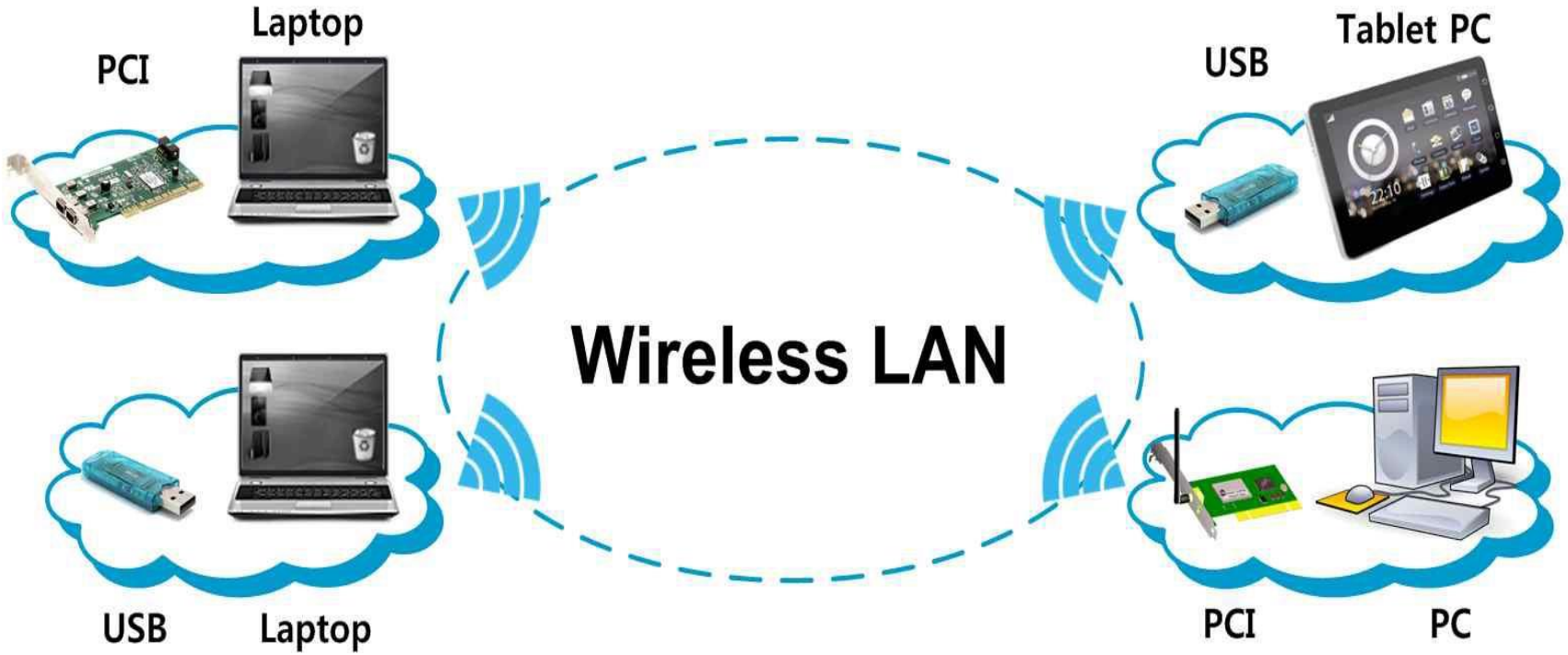
Ad-Hoc Mode

- Wi-Fi devices or stations communicate directly with each other, without help from an AP (Access Point) ➔ Used where Infrastructure Mode network setup is not needed or not possible
- Also referred to as peer-to-peer mode

- IBSS (Independent Basic Service Set)
  - Ad-hoc mode network is referred to as an IBSS

Wi-Fi

Example of Ad-Hoc mode



Wi-Fi

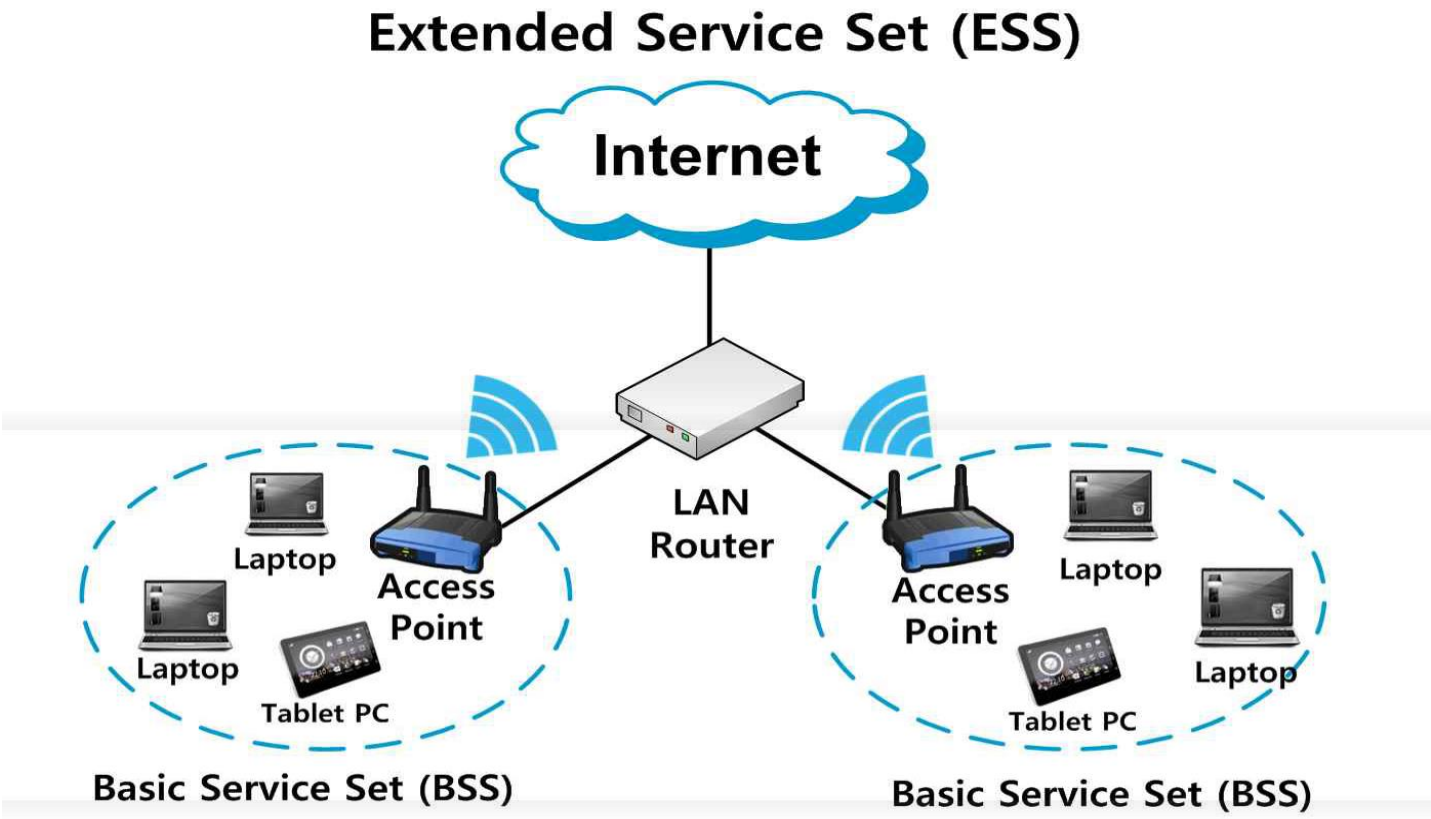
BSS & ESS

- BSS (Basic Service Set) is the basic building block of an 802.11 WLAN
  - In infrastructure mode, a BSS is formed by a single AP (Access Point) and all associated STAs (stations)
  - AP acts as a Master and controls all STAs within the BSS
- ESS (Extended Service Set) is a set of two or more BSSs that form a single network

  ➔ Extends the range of Wi-Fi STA mobility

Wi-Fi

Example of ESS



Wi-Fi

IEEE 802.11 Network PHY Standards (1/2)				
802.11 Protocol	Release Date	Frequency	Bandwidth	Stream Data Rate
802.11-1997	Jun. 1997	2.4 GHz	22 MHz	1, 2 Mbps
802.11a	Sep. 1999	5 GHz	20 MHz	6 ~ 54 Mbps
		3.7 GHz		
802.11b	Sep. 1999	2.4 GHz	22 MHz	1 ~ 11 Mbps
802.11g	Jun. 2003	2.4 GHz	20 MHz	6 ~ 54 Mbps
802.11n	Oct. 2009	2.4/5 GHz	20 MHz	7.2 ~ 72.2 Mbps
			40 MHz	15 ~ 150 Mbps

Wi-Fi

IEEE 802.11 Network PHY Standards (2/2)				
802.11 Protocol	Release Date	Frequency	Bandwidth	Stream Data Rate
802.11ac	Dec. 2013	5 GHz	20 MHz	7.2 ~ 96.3 Mbps
			40 MHz	15 ~ 200 Mbps
			80 MHz	32.5 ~ 433.3 Mbps
			160 MHz	65 ~ 866.7 Mbps
802.11ad	2012, 2016	60 GHz	2.16 GHz	Up to 7 Gbps
802.11ay	2017	60 GHz	8 GHz	Up to 100 Gbps

Wi-Fi

IEEE 802.11 Network PHY Standards (1/2)				
802.11 protocol	Frequency	Modulation	Approximate Range	
			Indoor (m)	Outdoor (m)
802.11-1997	2.4 GHz	DSSS, FHSS	20	100
802.11a	5 GHz	OFDM	35	120
	3.7 GHz		-	5000
802.11b	2.4 GHz	DSSS	35	140
802.11g	2.4 GHz	OFDM, DSSS	38	140

Wi-Fi

IEEE 802.11 Network PHY Standards (2/2)				
802.11 protocol	Frequency	Modulation	Approximate Range	
			Indoor (m)	Outdoor (m)
802.11n	2.4/5 GHz	OFDM (MIMO-4)*	70	250
802.11ac	5 GHz	OFDM (MIMO-8)*	35	-
802.11ad	60 GHz	OFDM (> 10 X 10 MIMO)	10	10

***MIMO-4 and MIMO-8 represent that the allowable MIMO streams are 4 and 8, respectively.**

Wi-Fi

Wi-Fi uses the ISM Band

- ISM (Industrial, Scientific and Medical) bands are radio frequency bands reserved internationally for the use of industrial, scientific, and medical purposes

- Devices using ISM bands will experience interference from other products operating in the same frequency band

Wi-Fi

ISM Band

Frequency range		Bandwidth	Center Frequency	Availability
6.765 MHz	6.795 MHz	30 kHz	6.780 MHz	Subject to local acceptance
13.553 MHz	13.567 MHz	14 kHz	13.560 MHz	Worldwide
26.957 MHz	27.283 MHz	326 kHz	27.120 MHz	Worldwide
40.660 MHz	40.700 MHz	40 kHz	40.680 MHz	Worldwide
433.050 MHz	434.790 MHz	1.74 MHz	433.920 MHz	local acceptance
902.000 MHz	928.000 MHz	26 MHz	915.000 MHz	local acceptance
2.400 GHz	2.500 GHz	100 MHz	2.450 GHz	Worldwide

Wi-Fi

ISM Band

Frequency range		Bandwidth	Center Frequency	Availability
5.725 GHz	5.875 GHz	150 MHz	5.800 GHz	Worldwide
24.000 GHz	24.250 GHz	250 MHz	24.125 GHz	Worldwide
61.000 GHz	61.500 GHz	500 MHz	61.250 GHz	Subject to local acceptance
122.000 GHz	123.000 GHz	1 GHz	122.500 GHz	Subject to local acceptance
244.000 GHz	246.000 GHz	2 GHz	245.000 GHz	Subject to local acceptance

Wi-Fi

Wi-Fi Interference

- Devices operating in the 2.4 GHz range include
  - IEEE802.15.4 devices: ZigBee, 6LoWPAN
  - Microwave ovens
  - Bluetooth
  - Baby monitors
  - Cordless telephones
  - Amateur radio equipment
  - etc.

Wi-Fi

Dual Band

- Unlike ordinary Wi-Fi equipment that only supports one signal band, dual band is the capability to transmit on the 5 GHz band of 802.11a, 802.11n, and 802.11ac and also the 2.4 GHz band used by 802.11b, 802.11g, and 802.11n

Wi-Fi

Example of Dual Band

Wi-Fi

Wi-Fi Direct

- Wi-Fi Direct devices can connect directly to one another without access to a traditional network
- Devices can make a one-to-one connection, or a group of several devices can connect simultaneously

Wi-Fi

Wi-Fi Direct

- With optional services, users can send files, print documents, play media, and display screens between and among devices

Wi-Fi

Tethering (Hotspot)

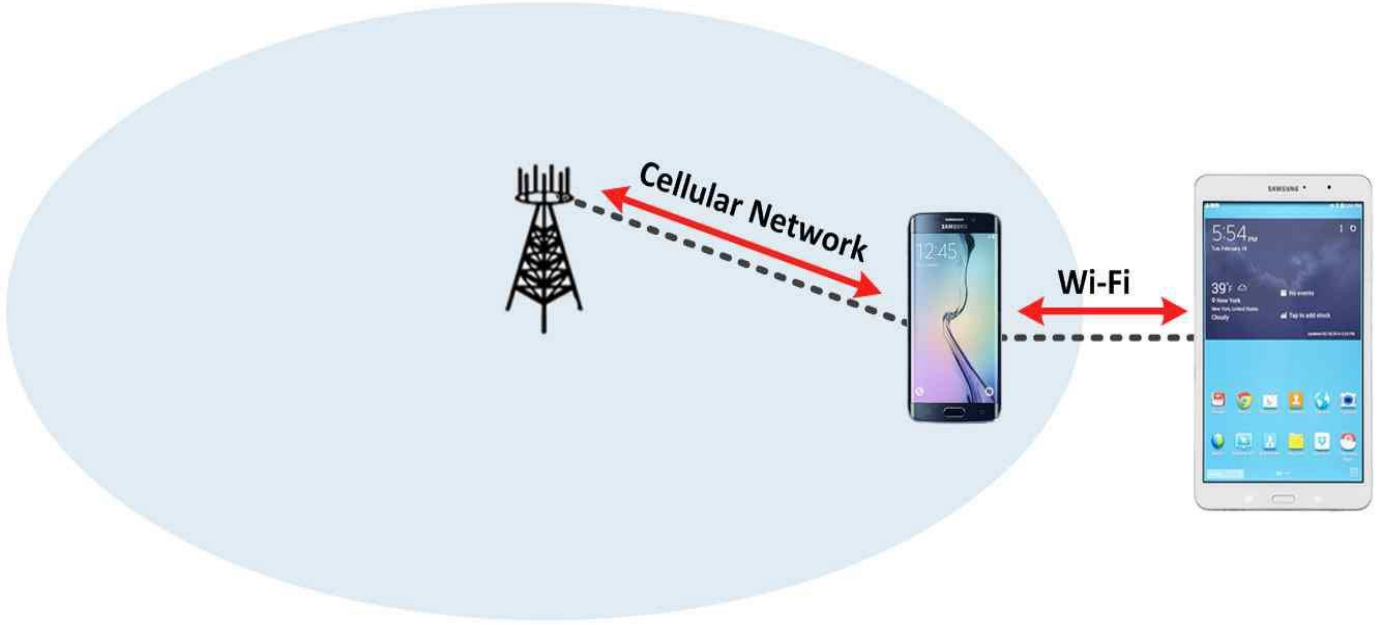
- Tethering refers to connecting one device to another

- In the context of mobile phones or Internet tablets, tethering allows sharing the Internet connection of the phone or tablet with other devices such as laptops

Wi-Fi

Tethering (Hotspot)

- **A Wi-Fi STA can make connection to the Internet by connecting to a smartphone using Wi-Fi**



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References

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