WIRELESS NETWORKS

OUTLINE

- Wireless Technology overview
- The IEEE 802.11 WLAN Standards

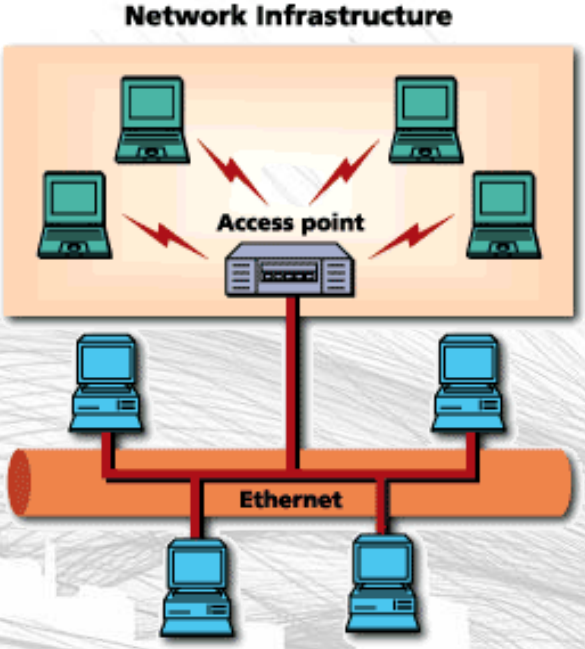
WIRELESS?

- A wireless LAN or WLAN is a wireless local area network that uses radio waves as its carrier.
- The last link with the users is wireless, to give a network connection to all users in a building or campus.
- The backbone network usually uses cables

COMMON TOPOLOGIES

The wireless LAN connects to a wired LAN

- There is a need of an access point that bridges wireless LAN traffic into the wired LAN.
- The access point (AP) can also act as a repeater for wireless nodes, effectively doubling the maximum possible distance between nodes.



COMMON TOPOLOGIES

Complete Wireless Networks

- The physical size of the network is determined by the maximum reliable propagation range of the radio signals.
- Referred to as **ad hoc** networks
- Are self-organizing networks without any centralized control
- Suited for temporary situations such as meetings and conferences.

HOW DO WIRELESS LANS WORK?

- Wireless LANs operate in almost the same way as wired LANs, using networking protocols and supporting most of the same applications.

HOW ARE WLANS DIFFERENT?

- They use specialized **physical and data link** protocols
- They integrate into existing networks through **access points** which provide a bridging function
- They let you stay connected as you **roam** from one coverage area to another
- They have unique **security** considerations
- They have specific **interoperability** requirements
- They require **different hardware**
- They offer **performance** that differs from wired LANs.

PHYSICAL AND DATA LINK LAYERS

Physical Layer:

- The wireless **NIC** takes **frames** of data from the link layer, scrambles the data in a predetermined way, then uses the modified data stream to modulate a **radio carrier signal**.

Data Link Layer:

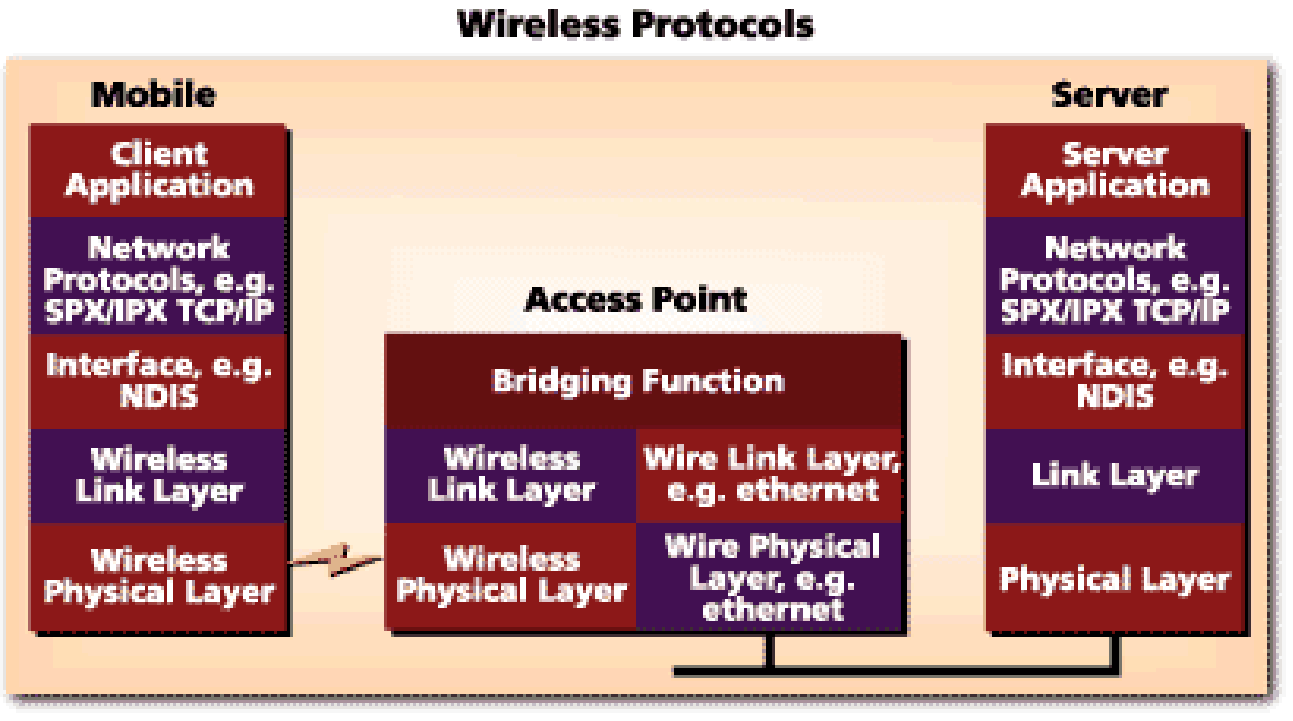
- Uses **C**arriers-**S**ense-**M**ultiple-**A**ccess with **C**ollision **A**voidance (CSMA/CA).

NIC: network interface controller

INTEGRATION WITH EXISTING NETWORKS

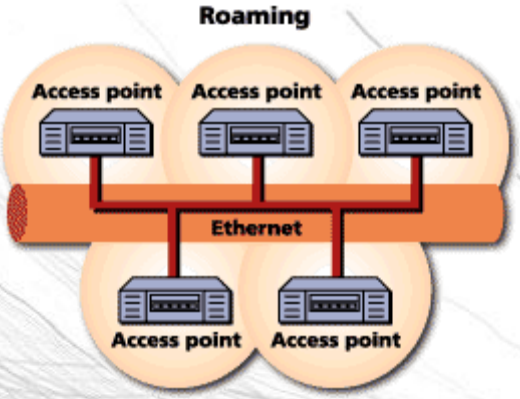
- Wireless Access Points (APs) - a small device that bridges wireless traffic to your network.
- Most access points bridge wireless LANs into Ethernet networks, but Token-Ring options are available as well.

INTEGRATION WITH EXISTING NETWORKS



ROAMING

- Users maintain a continuous connection as they roam from one physical area to another
- Mobile nodes automatically register with the new access point.
- Methods: DHCP, Mobile IP

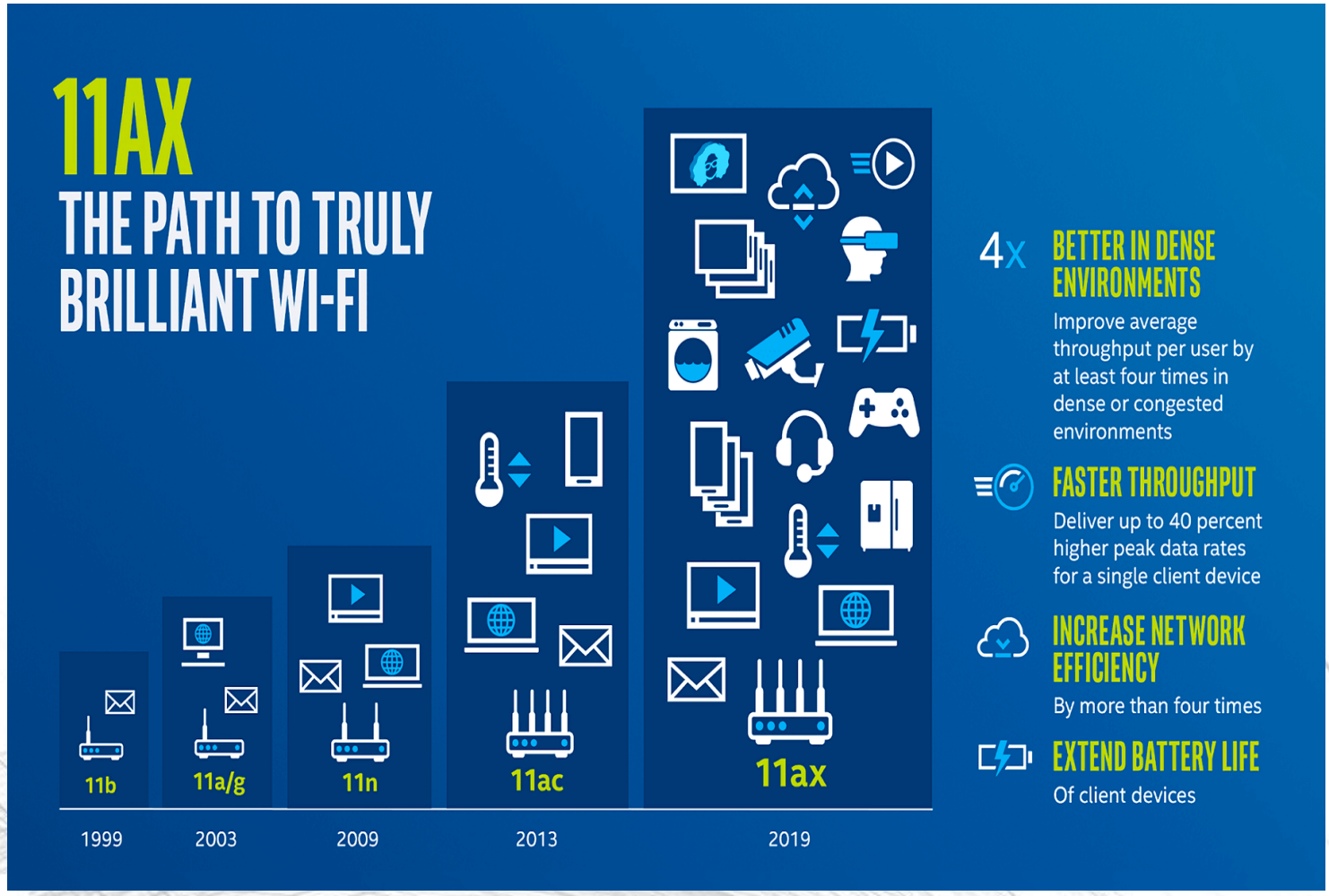


INTEROPERABILITY

- Before the IEEE 802.11 interoperability was based on cooperation between vendors.
- IEEE 802.11 only standardizes the physical and medium access control layers.
- Vendors must still work with each other to ensure their IEEE 802.11 implementations interoperate
- Wireless Ethernet Compatibility Alliance (WECA) introduces the Wi-Fi Certification to ensure cross-vendor interoperability of 802.11b solutions

WHAT IS 802.11?

- A family of wireless LAN (WLAN) specifications developed by a working group at the Institute of Electrical and Electronic Engineers (IEEE)
- Defines standard for WLANs using the following four technologies
  - Frequency Hopping Spread Spectrum (FHSS)
  - Direct Sequence Spread Spectrum (DSSS)
  - Infrared (IR)
  - Orthogonal Frequency Division Multiplexing (OFDM)
- Versions: 802.11a, 802.11b, 802.11g, 802.11e, 802.11f, 802.11i, 802.11n, 802.11ac, 802.11ax



IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac	802.11ax
Year Released	1999	1999	2003	2009	2014	2019
Frequency	5Ghz	2.4GHz	2.4GHz	2.4Ghz & 5GHz	2.4Ghz & 5GHz	2.4Ghz & 5GHz
Maximum Data Rate	54Mbps	11Mbps	54Mbps	600Mbps	1.3Gbps	10-12Gbps

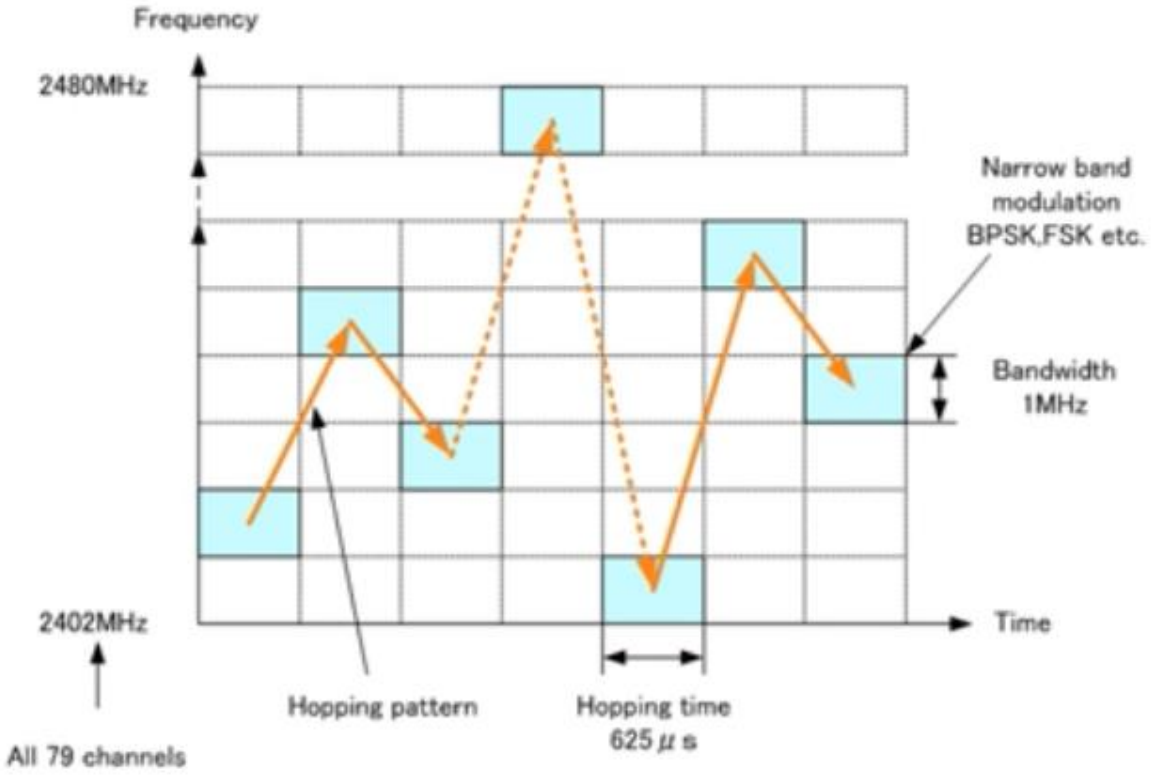
802.11 - TRANSMISSION

- Most wireless LAN products operate in unlicensed radio bands
  - 2.4 GHz is most popular
  - Available in most parts of the world
  - No need for user licensing
- Most wireless LANs use spread-spectrum radio
  - Resistant to interference, secure
  - Two popular methods
    - Frequency Hopping (FH)
    - Direct Sequence (DS)

Frequency Hopping Spread Spectrum

Sender don't use single frequency to transmit data. Multiple frequency is used for transmission.

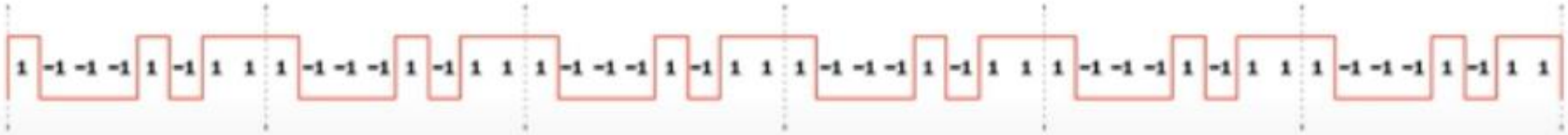
Sender send data using frequency f1 for 625 micro second and then change frequency.



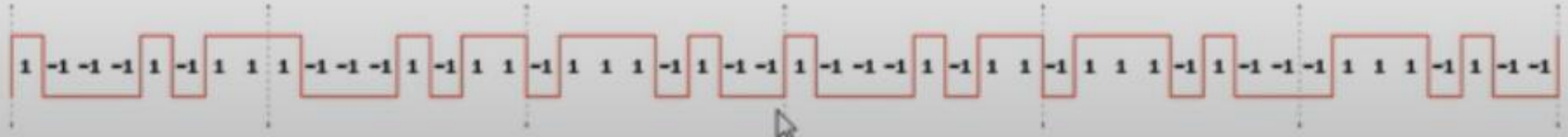
Direct Sequence Spread Spectrum

Low-Bandwidth Signal:

High-Bandwidth Spreading Code:



Mix is a simple multiply



FREQUENCY HOPPING VS. DIRECT SEQUENCE

- FH systems use a radio carrier that “hops” from frequency to frequency in a pattern known to both transmitter and receiver
  - Easy to implement
  - Resistance to noise
  - Limited throughput (2-3 Mbps @ 2.4 GHz)
- DS systems use a carrier that remains fixed to a specific frequency band. The data signal is spread onto a much larger range of frequencies (at a much lower power level) using a specific encoding scheme.
  - Much higher throughput than FH (11 Mbps)
  - Better range
  - Less resistant to noise (made up for by redundancy – it transmits at least 10 fully redundant copies of the original signal at the same time)

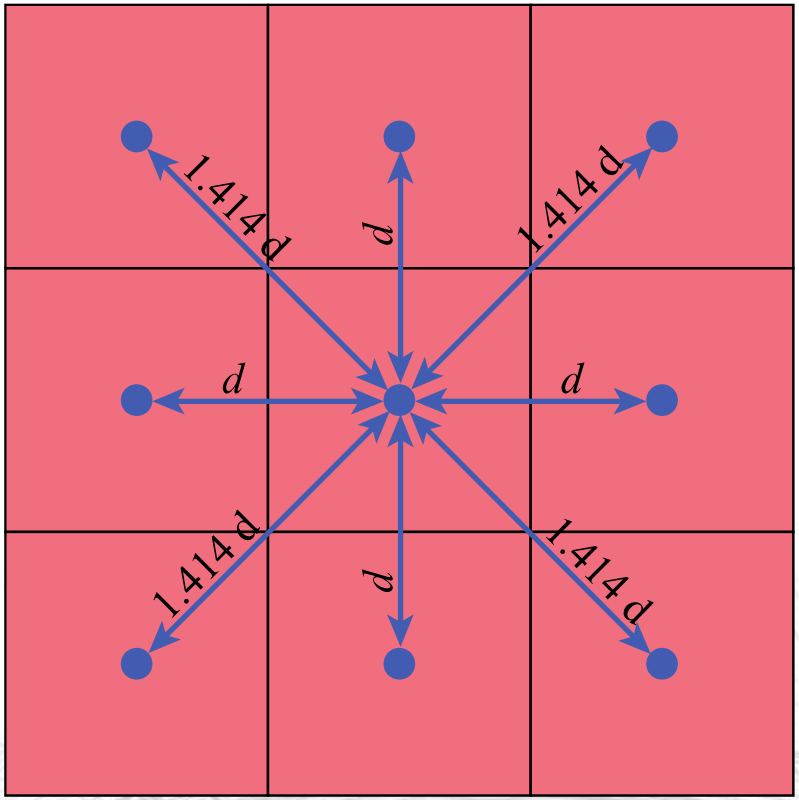
CELLULAR WIRELESS NETWORKS

CELLULAR NETWORKS

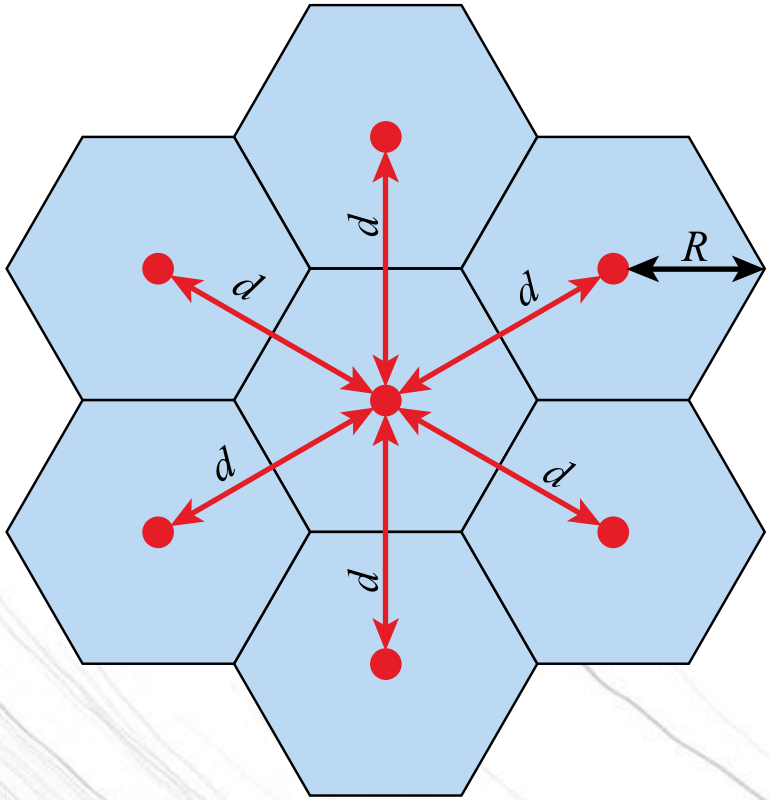
- Revolutionary development in data communications and telecommunications
- Foundation of mobile wireless
  - Telephones, smartphones, tablets, wireless Internet, wireless applications
- Supports locations not easily served by wireless networks or WLANs
- Five generations of standards
  - 1G: Analog
  - 2G: Still used to carry voice
  - 3G: First with sufficient speeds for data networking, packets only
  - 4G: Truly broadband mobile data up to 1 Gbps
  - 5G: 5G speeds will range from ~50 Mbit/s to over 2 Gbit/s at the start.[1] The fastest 5G, known as mmWave, delivers speeds of up to and over 2 Gbit/s. As of July 3, 2019, mmWave had a top speed of 1.8 Gbit/s[2] on AT&T's 5G network. There is a huge difference between the peak speed of 5G and 4G, the minimum peak download speed on a 4G network is 1Gbps while 5G is known to deliver peak download speed of 20 Gbps.

CELLULAR NETWORK ORGANIZATION

- Use multiple low-power transmitters (100 W or less)
- Areas divided into cells
  - Each served by its own antenna
  - Served by base station consisting of transmitter, receiver, and control unit
  - Band of frequencies allocated
  - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)

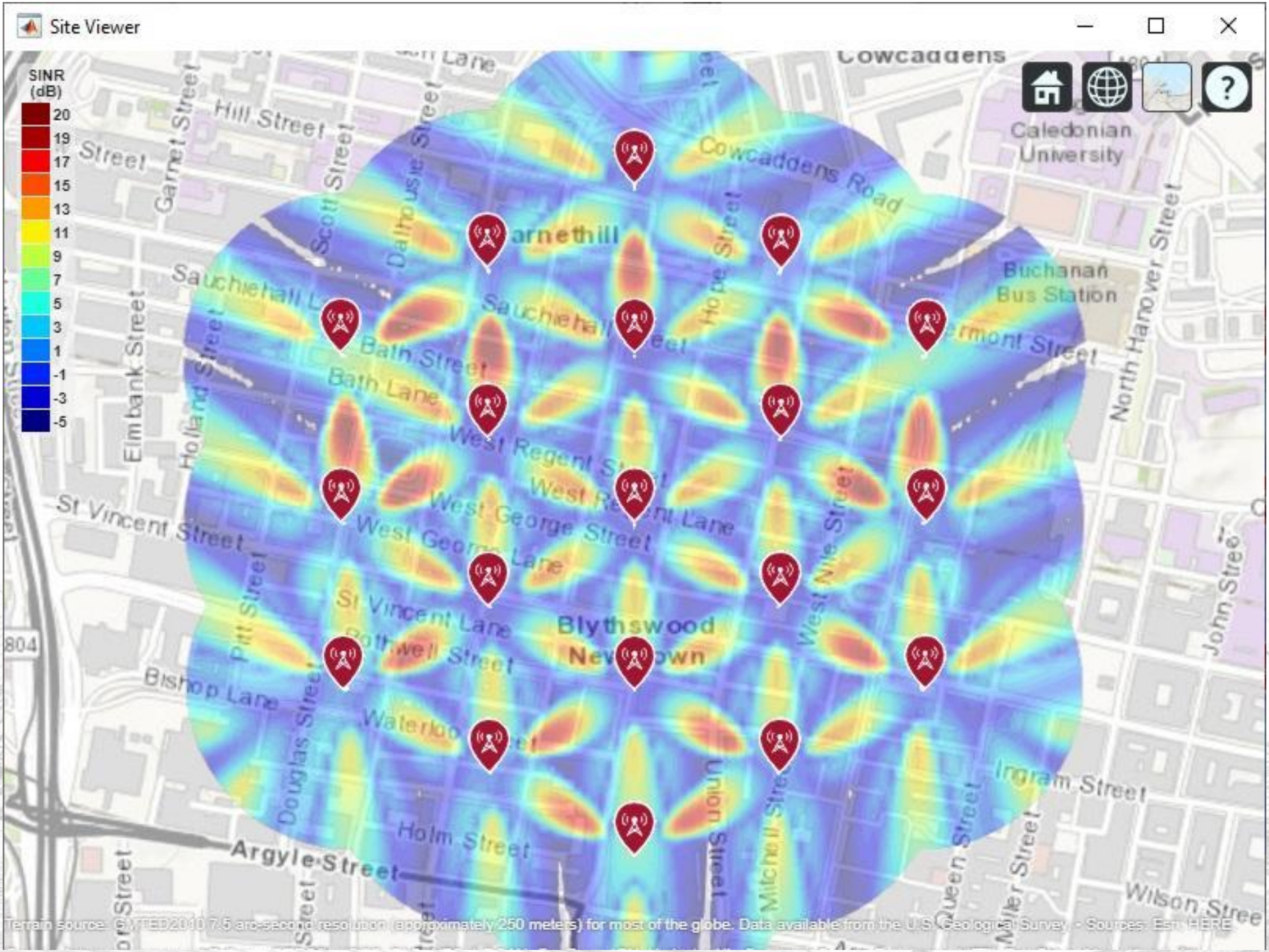


(a) Square pattern



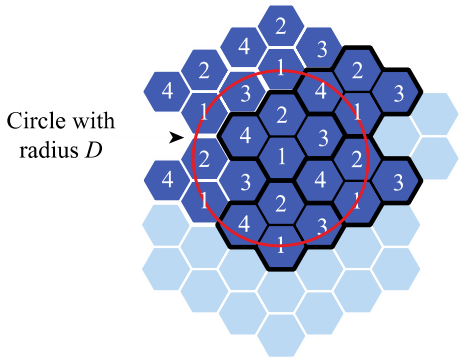
(b) Hexagonal pattern

13.1 CELLULAR GEOMETRIES

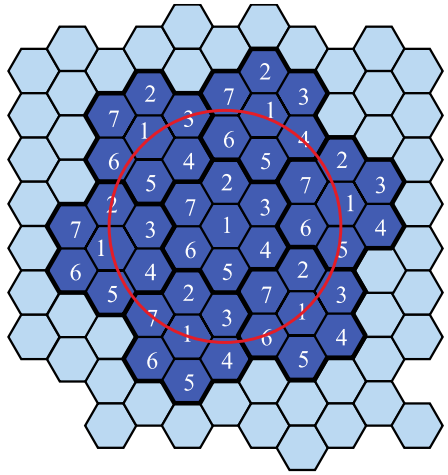

Site Viewer
SINR (dB)
20
19
17
15
13
11
9
7
5
3
1
-1
-3
-5
Cowcaddens
Caledonian University
Cowcaddens Road
Garnethill
Buchanan Bus Station
Sauchiehall Street
Bath Street
Bath Lane
West Regent Street
West George Street
St Vincent Street
St Vincent Lane
Blythswood New Town
Bothwell Street
Bishop Lane
Waterloo Street
Holm Street
Argyle Street
Ingram Street
Wilson Street
Elmbank Street
Holland Street
Scott Street
Dalhousie Street
Hope Street
North Hanover Street
Vermont Street
West Nile Street
Pitt Street
Douglas Street
Union Street
Mitchell Street
Queen Street
Miller Street
John Street
Hill Street
Garnet Street
804
Terrain source: GMTED2010 7.5 arc-second resolution (approximately 250 meters) for most of the globe. Data available from the U.S. Geological Survey. - Sources: Esri, HERE

FREQUENCY REUSE

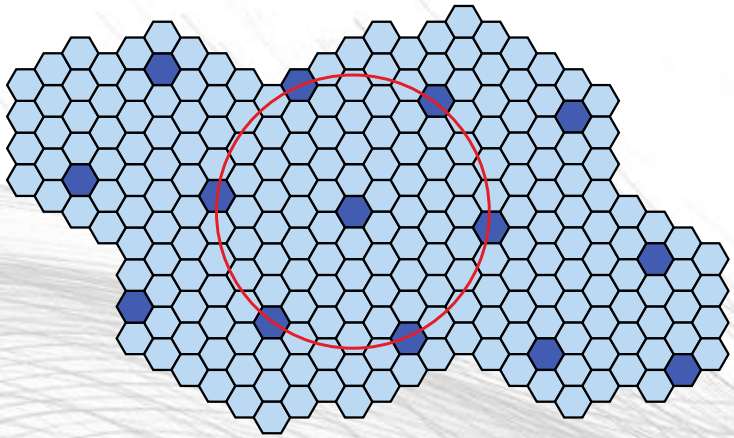
- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
  - 10 to 50 frequencies assigned to each cell
  - Transmission power controlled to limit power at that frequency escaping to adjacent cells
  - The issue is to determine how many cells must intervene between two cells using the same frequency



(a) Frequency reuse pattern for $N = 4$



(b) Frequency reuse pattern for $N = 7$



(c) Black cells indicate a frequency reuse for $N = 19$

13.2 FREQUENCY REUSE PATTERNS

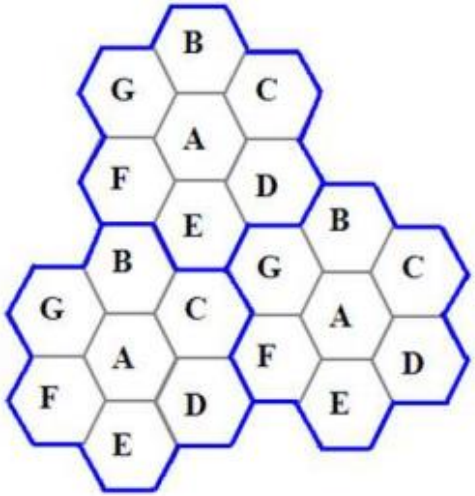
CELL CLUSTER - FREQUENCY REUSE PATTERNS

Considering a cellular system that has a total of S duplex radio channels. If each cell is allocated a group of k channels ($k < S$)and if the S channels are divided among N cellsinto unique and disjoint channel groups of same number of channels, then,

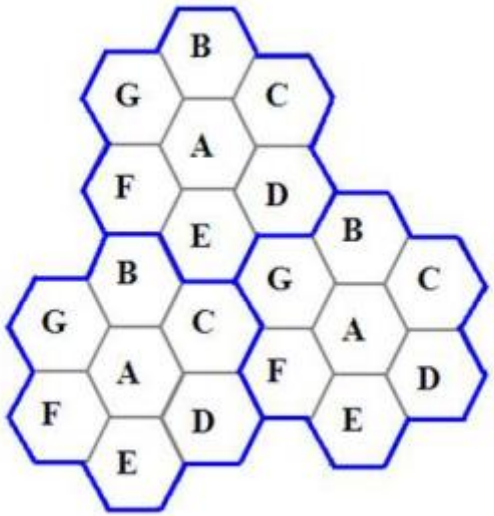
$$S = kN. \qquad 6.1$$

The N cells that collectively use the complete set of available frequencies is called a cluster. If a cluster is replicated M times within the system, the total number of duplex channels or capacity,

$$C = MkN = MS. \qquad 6.2$$



CELL CLUSTER - FREQUENCY REUSE PATTERNS

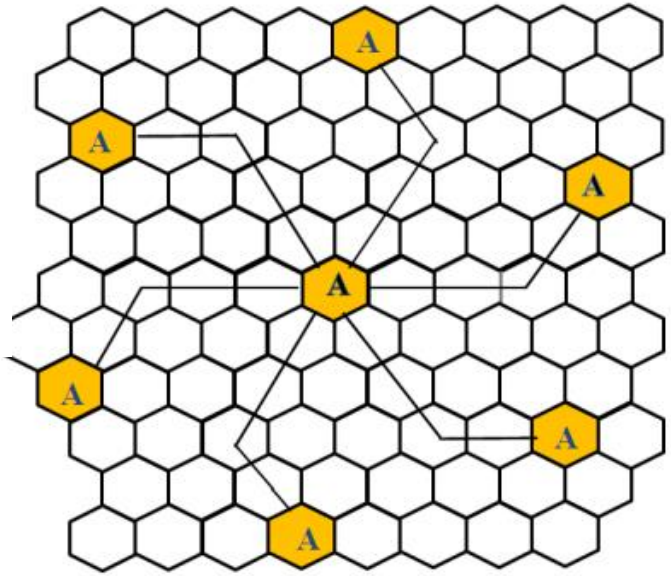


In this example,
The cluster size N = 7 and the frequency reuse factor is 1/7 since each cell contains one-seventh of the total number of available channels.

The capacity is directly proportional to M. The factor N is called the cluster size and is typically 4, 7 or 12. If the cluster size N is reduced while the cell size is kept constant, more clusters are required to cover a given area and hence more capacity is achieved from the design viewpoint, the smallest possible value of N is desirable to maximize capacity over a given coverage area. The frequency reuse factor of a cellular system is 1/N,since each cell within a cluster is assigned 1/N of the total available channels in the system.

CO-CHANNEL CELLS

In this example, N = 19 (i.e., i = 3, j = 2).
Where,
i and j are non-negative integers.
To find the nearest co-channel neighbours of a particular cell,
a. move i cells along any chain of hexagons then,
b. turn 60 degrees counter-clockwise and move j cells.



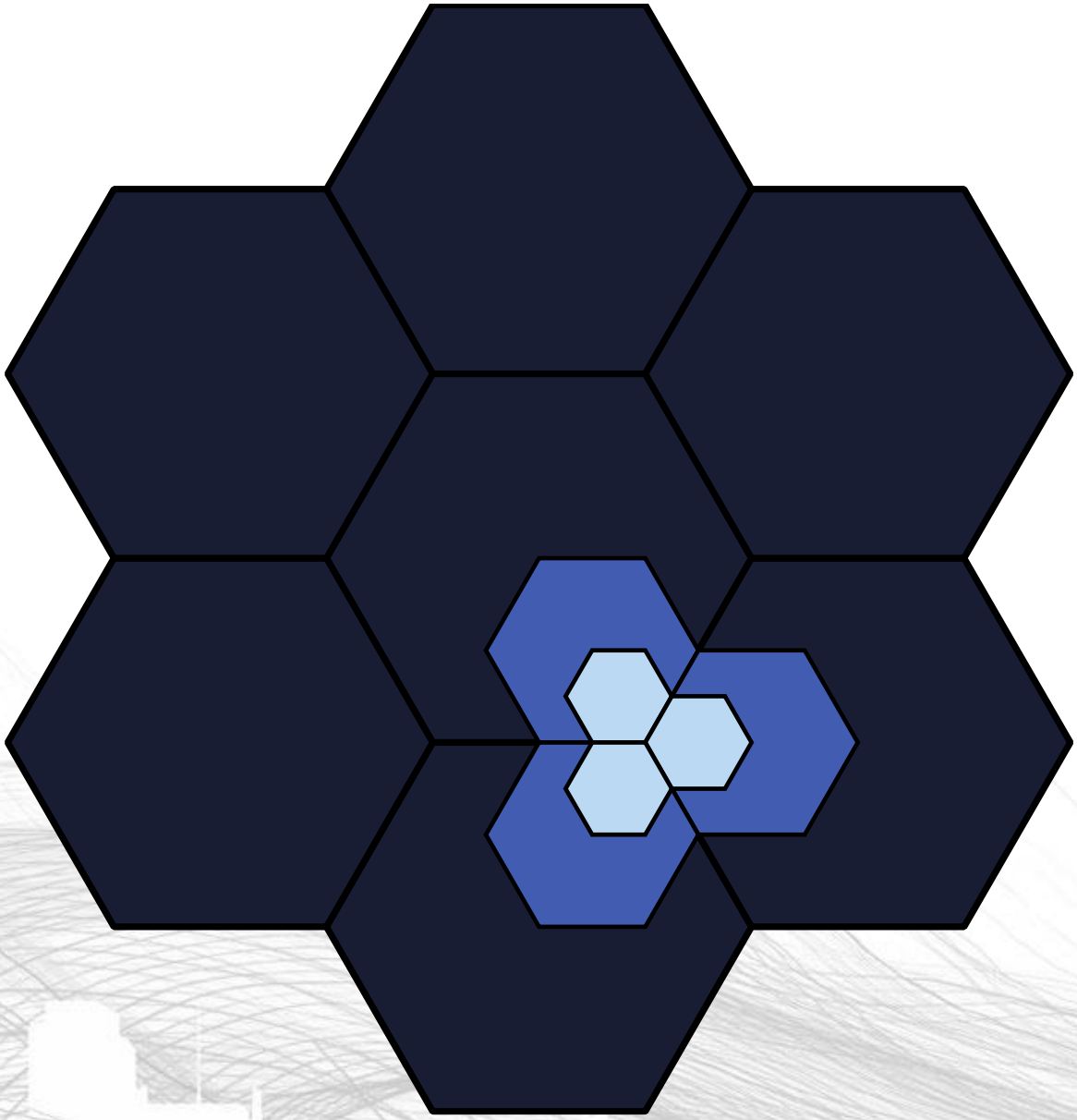
Method of locating co-channel cells in a cellular system. In this figure, N=19(i.e, i =3, j=2).

A larger cluster size causes the ratio between the cell radius and the distance between co-channel cells to decrease reducing co-channel interference. The value of N is a function of how much interference a mobile or base station can tolerate while maintaining a sufficient quality of communications. Since each hexagonal cell has six equidistant neighbors and the line joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees, only certain cluster sizes and cell layouts are possible. To connect without gaps between adjacent cells, the geometry of hexagons is such that the number of cells per cluster, N, can only have values that satisfy,

$$N = i^2 + ij + j^2, \qquad 6.3$$

APPROACHES TO COPE WITH INCREASING CAPACITY

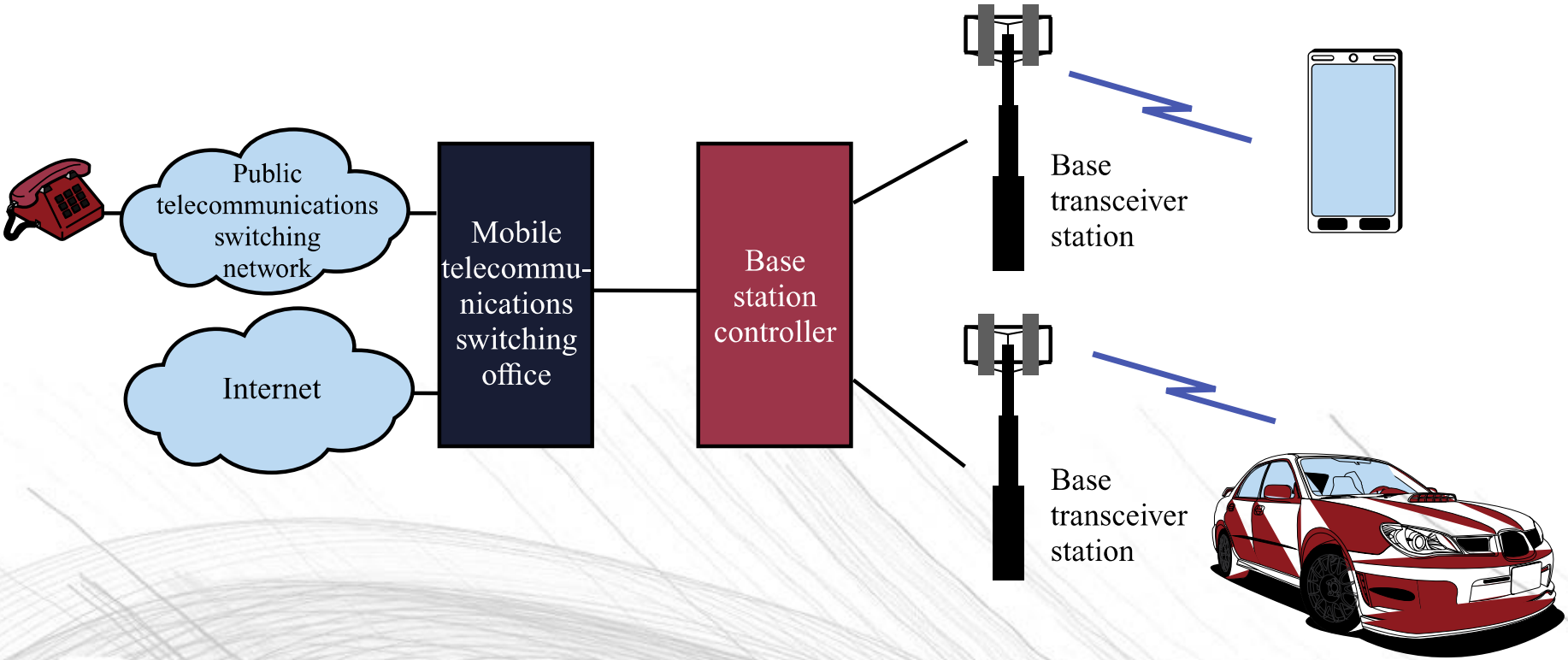
- Adding new channels
- Frequency borrowing – frequencies are taken from adjacent cells by congested cells
- Cell splitting – cells in areas of high usage can be split into smaller cells
- Cell sectoring – cells are divided into a number of wedge-shaped sectors, each with their own set of channels
- Network densification – more cells and frequency reuse
  - Microcells – antennas move to buildings, hills, and lamp posts
  - Femtocells – antennas to create small cells in buildings
- Interference coordination – tighter control of interference so frequencies can be reused closer to other base stations
  - Inter-cell interference coordination (ICIC)
  - Coordinated multipoint transmission (CoMP)



13.3 CELL SPLITTING

CELLULAR SYSTEMS TERMS

- Base Station (BS) – includes an antenna, a controller, and a number of receivers
- Mobile telecommunications switching office (MTSO) – connects calls between mobile units
- Two types of channels available between mobile unit and BS
  - Control channels – used to exchange information having to do with setting up and maintaining calls
  - Traffic channels – carry voice or data connection between users



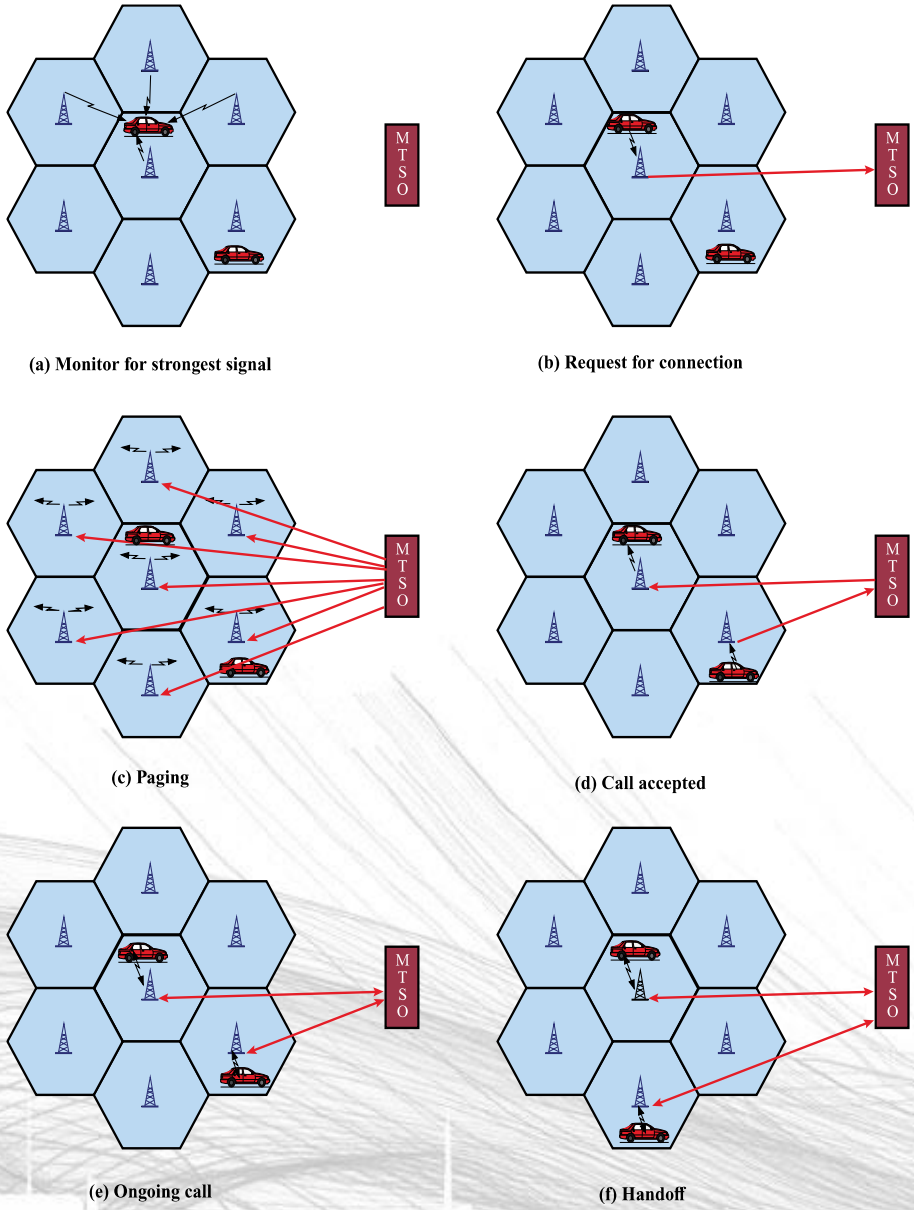
13.5 OVERVIEW OF CELLULAR SYSTEM

STEPS IN AN MTSO CONTROLLED CALL BETWEEN MOBILE USERS

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

In cellular telecommunications, the terms handover or handoff refer to the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service.

Paging is the one-to-one communication between the **mobile** and the base station
• **Paging** is a procedure the **network** uses to find out a subscriber's location before actual call establishment. **Paging** is used to alert the **mobile** station of an incoming call.



13.6 EXAMPLE OF MOBILE CELLULAR CALL

Thank You