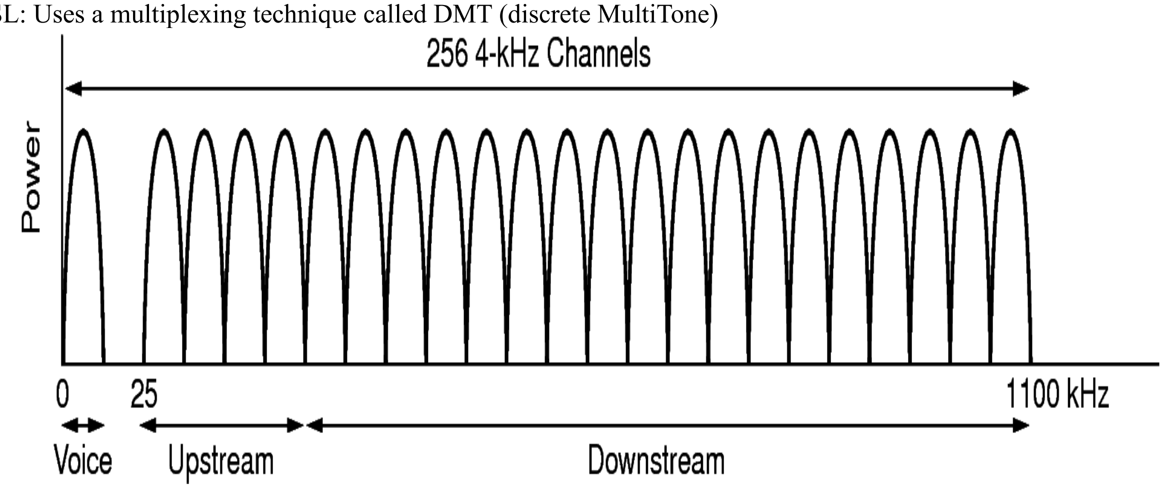
Lecture 7
Plan: Examples of three communication networks. Focus on mobile networks
review: QAM ideas, physical medium (guided/unguided), multiplexing(FDM,WDM,TDM), switching

Today, we will cover three existing communication networks
Public telephone system, cable TV systems, and the mobile telephone networks

Q:/ Why should we study them?
A:/ all three of them provides the basic means of network communications though they were originally designed for other purposes.

1. Public telephone system
Originally for voice communications (300Hz to 3400Hz, though people usually say that the bandwidth is 4000Hz).
Structure: hierarchical

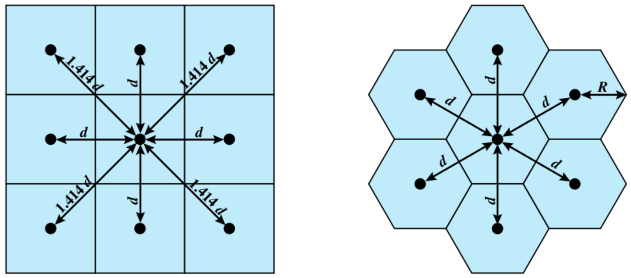
- start with a star network, phones are connected to a hub (aka end office) via local loop. Then end offices were connected to the toll office, Then toll offices are connected to switching office, etc.
- the local loops are UTP's with a bandwidth around 1.1MHz.
  Q:/ Why do we say that the bandwidth is 4000Hz or 3100Hz?
  A:/ A filter at the end office cuts off anything below 300Hz and above 3400Hz.
  Q:/ How to bypass the filter to get all the 1.1MHz bandwidth?
  A:/ Pay (or call it subscribe). DSL (digital sub line)
- DSL: Uses a multiplexing technique called DMT (discrete MultiTone)



total channels 256
1 is used for voice
5 are unused to separate data from voice
250 are for data
ADSL – more downstream than upstream (no less than 32)
each channel uses FSK with QAM-32768, baud rate of 4000. → With 220 channels, data speed can reach 13.2Mbps
Usually that's not possible (8Mbps downstream, 1Mbps upstream)

2. Mobile telephone system (Cellular phone)
Q:/ Why is it called cell phone?
A:/ the phones reside in cells (geographically region that belong to a base tower)

Q:/ What is the shape of a cell?
A:/ Most of time, it's a hexagon.
Q:/ Why?
A:/ compare hexagon with a square.



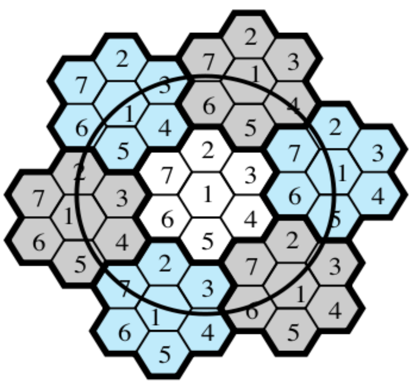
(a) Square pattern (b) Hexagonal pattern

Hexagon ensures that the distance among cells are equal(the radius of the circle circumscribes the hexagon. Also the edge of the hexagon is the same as the radius.

First cell phone (car phone) in 1946

1. First generation (analog) -- The analog voice signal is sent directly over the air.

    Cells are about 6.5-13 km in size with a base station at the center of each cell
    frequency reuse - adjacent cells uses different frequency while frequencies can be reused by nearby cells

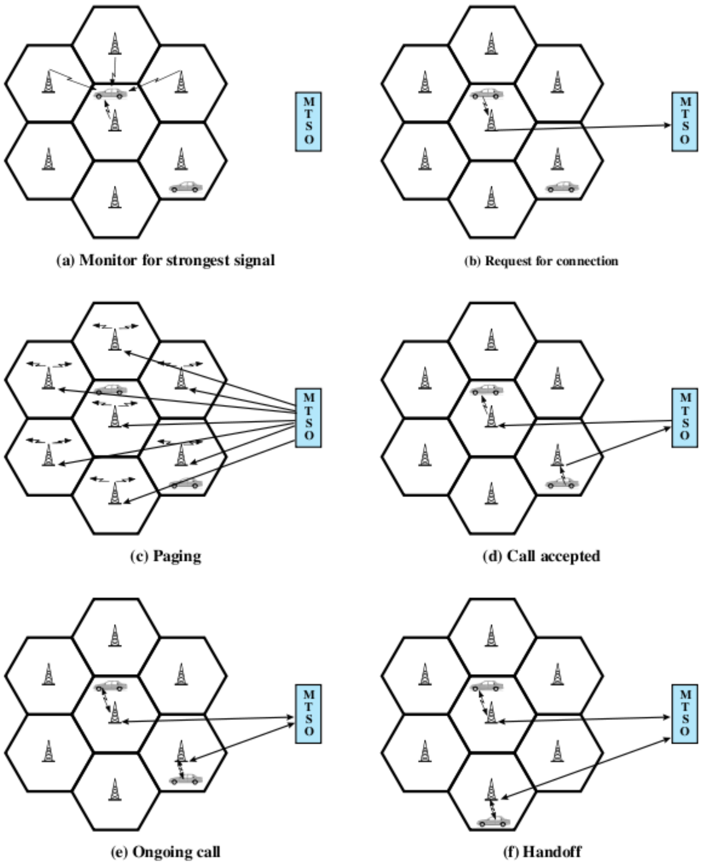


Two 25MHz bands were used for AMPS (advanced Mobile Phone Service) (869M-894M for base -->cell and 824-849 for cell-->base)
FDM is used to split the band into 832 simplex channels with 21 channels for controls (each operator can only get half of it to ensure competition)

Q:/ What is the bandwidth of each channel?
A:/ 25M/832=30K

Usually, less than 50 channels are assigned to each cell.

Q:/ How do we make a cell phone call?
A:/



Initialization. When the phone is on, it initializes by scanning for the base with strongest signal. Then register with the MTSO (mobile telecommunication switching office) with its unique serial number and the phone number. This process repeats about every 15 minutes.
Call-Origination. When call another cell phone, first, cell phone checks if the control channel to base is free. If yes, the target number will be sent to MSTO via the base station.
Paging. MSTO sends a paging message to BS according to the target number . BS will broadcast the message to all their registered cell phones.
Call Accepted. Target cell phone answers the message to MSTO via its own BS. MSTO then selects free traffic channels in both BS's and tell the cell phones via their own BS. Cell phones then switch to the designated channels and the connection is made
Hand off: If one mobile user steps outside its current cell, the service will be cut in the first genreration system. (hard handoff). In the 2nd and 3rd, small control messages were inserted to ensure that the call is maintained while handoff happens (about 300ms)

Second generation (digital) – The analog voice is compressed and digitalized, then modulated and sent. (like a smaller modem inside the phone)

There are several different schemes
D-AMPS (Digital Advanced Mobile Phone System) and GSM– Similar to AMPS except there are additional bands available around 1900MHz
CDMA (Code Division Multiple Access) – The most promising scheme.

Idea: AMPS, D-AMPS, and GSM follow the same pattern (divide the frequency bands into small segments and each of them will be used for voice/data).
Q:/ How about we let one user use all the available bandwidth and at the same time, allow all of them to use the whole bandwidth?
A:/ Use coding schemes.

E.g. FDM: people talking at diffferent places in the lobby. So it's ok.
TDM: people talk at turns
CDMA: People talk with different languages (they can talk at the same time and not necessarily at different places)

Q:/ How is it possible?
A:/ We have to give them different languages (chip sequences to represent 1 and 0)

each sender is given a unique sequence – chip sequence
The receiver knows the chip sequence of every sender inside its range.

Q:/ How will this be better than GSM?
A:/ For example, if we have a 1Mhz band available. If we use GSM with 100 stations, then each station can have only 10Khz. If we use CDMA, if the sequence number is less than 100, CDMA is better.

e.g.

(a)	(b)
A: 0 0 0 1 1 0 1 1	A: (−1 −1 −1 +1 +1 −1 +1 +1)
B: 0 0 1 0 1 1 1 0	B: (−1 −1 +1 −1 +1 +1 +1 −1)
C: 0 1 0 1 1 1 0 0	C: (−1 +1 −1 +1 +1 +1 −1 −1)
D: 0 1 0 0 0 0 1 0	D: (−1 +1 −1 −1 −1 −1 +1 −1)

Six examples:

– – 1 –	**C**	$S_1 = (-1\ +1\ -1\ +1\ +1\ +1\ -1\ -1)$
– 1 1 –	**B + $\underline{C}$**	$S_2 = (-2\ \ 0\ \ 0\ \ 0\ +2\ +2\ \ 0\ -2)$
1 0 – –	**A + $\underline{B}$**	$S_3 = (\ 0\ \ 0\ -2\ +2\ \ 0\ -2\ \ 0\ +2)$
1 0 1 –	**A + B + C**	$S_4 = (-1\ +1\ -3\ +3\ +1\ -1\ -1\ +1)$
1 1 1 1	**A + B + $\underline{C}$ + D**	$S_5 = (-4\ \ 0\ -2\ \ 0\ +2\ \ 0\ +2\ -2)$
1 1 0 1	**A + B + $\overline{C}$ + D**	$S_6 = (-2\ -2\ \ 0\ -2\ \ 0\ -2\ +4\ \ 0)$

(c)

$S_1 \bullet C = (1\ +1\ +1\ +1\ +1\ +1\ +1\ +1)/8 = 1$
$S_2 \bullet C = (2\ +0\ +0\ +0\ +2\ +2\ +0\ +2)/8 = 1$
$S_3 \bullet C = (0\ +0\ +2\ +2\ +0\ -2\ +0\ -2)/8 = 0$
$S_4 \bullet C = (1\ +1\ +3\ +3\ +1\ -1\ +1\ -1)/8 = 1$
$S_5 \bullet C = (4\ +0\ +2\ +0\ +2\ +0\ -2\ +2)/8 = 1$
$S_6 \bullet C = (2\ -2\ +0\ -2\ +0\ -2\ -4\ +0)/8 = -1$

(d)

Key idea: the chip sequences must be orthogonal and codes are linearly combined.

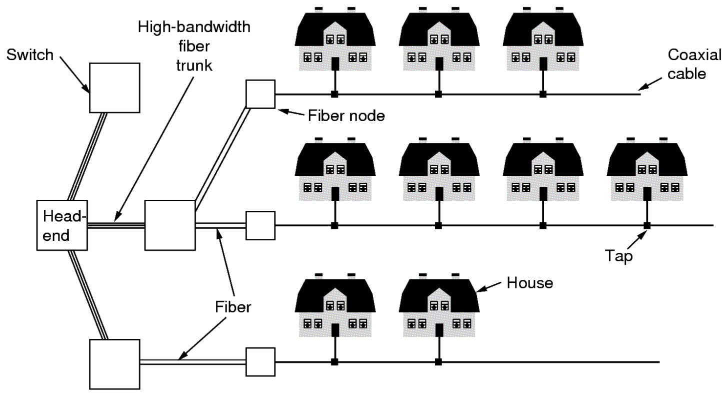
Note the orthogonal idea: AB=0, AC=0, etc, $AA = 1, A\bar{A} = -1$

e.g. For C, we can find what it sent over in the 6 messages.

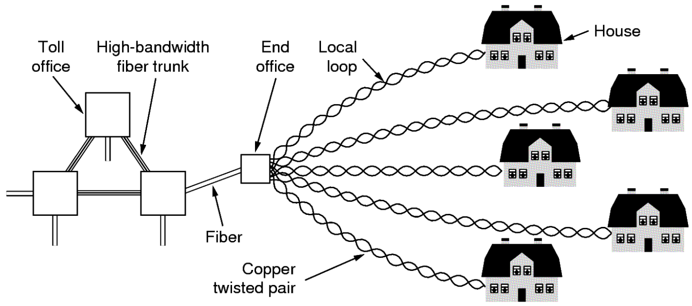
Must assume that there is synchronization. Or other measures must be taken to compensate.

2. Third Generation and beyond
   The idea is there are *digital voice and data.*
   It is required that the stationary user has 2Mbps, walking pedestrian has 384 kbps, and in car should have 144kbps.
   Candidates:
   UMTS(Universal Mobile Telecommunication System used in Europe, China): a hybrid model to allow W-CDMA and GSM to co-exist
   CDMA2000: Used in US to be able to compatible with IS-95.

3. Cable TV – designed for one-way broadcast– neighbors matter

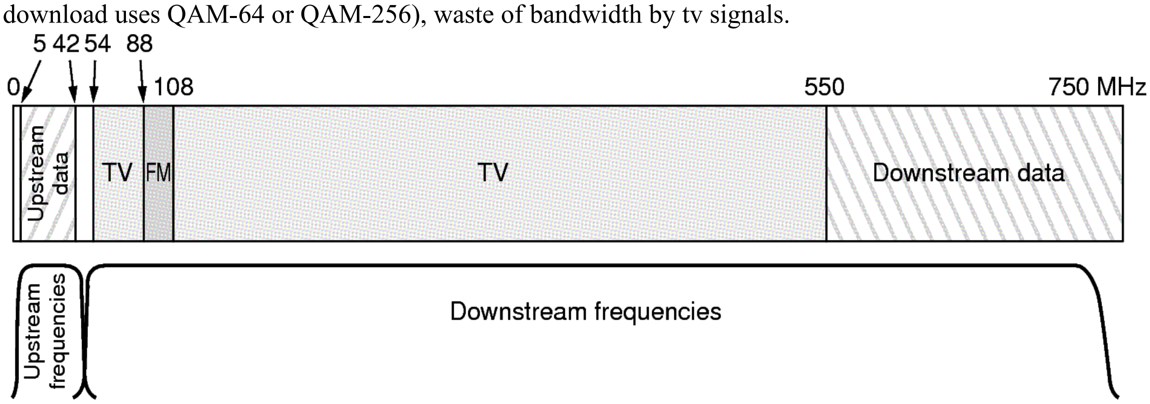


(a)



(b)

Uses cable modem to use the un-used frequencies offered by co-axial– asymmetric (upload uses QPSk and download uses QAM-64 or QAM-256), waste of bandwidth by tv signals.



Compared with ADSL:
ADSL is more secure and more predictable
Cable has more bandwidth but have to share with neighbors.