Lec13

Thursday, February 13, 2020 1:13 PM

Channel reservation - 10min

Thursday, February 21, 2008 4:29 PM

In practice, we want handoff calls receive a smaller amount of blocking.

- Users find calls blocked in mid-progress a far greater irritation than unsuccessful call attempts

Channel Reservation

Reserve a certain portion of the total channel pool in a cell for handoff uses only.

N : total # of channels

K : # of channels accessible by new calls

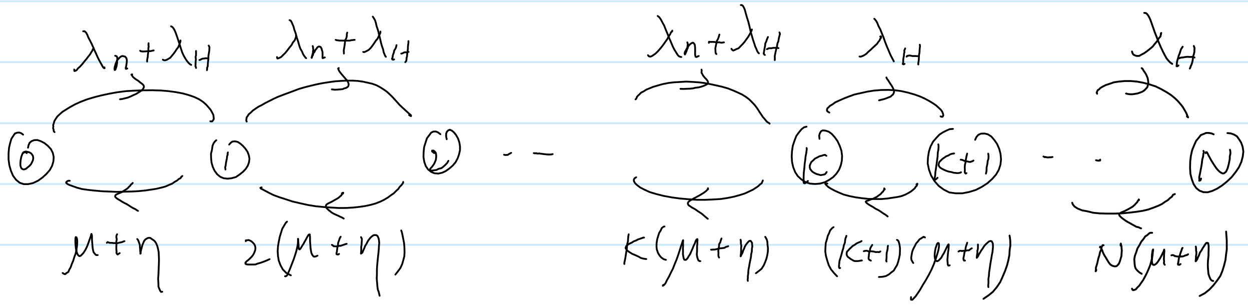
$K \le N$

All channels can be accessed by handoff calls.

When $n < K$, both new calls & handoff calls are accepted.

When $K \le n < N$, only handoff calls are accepted

When $n = N$, neither new calls nor handoff calls are accepted.



Let $\Lambda = \lambda_n + \lambda_H$

$\mu_c = \mu + \eta$

Write down the balance equations

$$\begin{cases} P_{n-1}\Lambda = P_n \cdot \mu_c \cdot n & \text{when } n \le K \\ P_{n-1}\lambda_H = P_n \cdot \mu_c \cdot n & n > K \end{cases}$$

$$\Rightarrow \quad P_n = \begin{cases} P_0 \left(\frac{\Lambda}{\mu_c}\right)^n \frac{1}{n!} & \text{when } n \le K \\ P_0 \left(\frac{\Lambda}{\mu_c}\right)^K \left(\frac{\lambda_H}{\mu_c}\right)^{n-K} \cdot \frac{1}{n!} & \text{when } n > K \end{cases}$$

Using $\sum_{n=0}^{N} P_n = 1$, solve p_0

$$P_0 = \frac{1}{\sum_{n=0}^{K} \left(\frac{\Lambda}{\mu_c}\right)^n \frac{1}{n!} + \sum_{n=K+1}^{N} \left(\frac{\Lambda}{\mu_c}\right)^K \left(\frac{\lambda_H}{\mu_c}\right)^{n-K} \cdot \frac{1}{n!}}$$

Prob. of handoff call blocking

$$P_{BH} = P_N$$

Prob. of new call blocking

$$P_{Bn} = \sum_{n=K}^{N} P_n$$

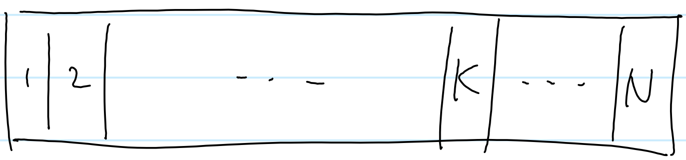
60

Channel reservation - handout

Thursday, February 21, 2008 4:29 PM

Channel Reservation

Reserve a certain portion of the total channel pool in a cell for handoff uses only.



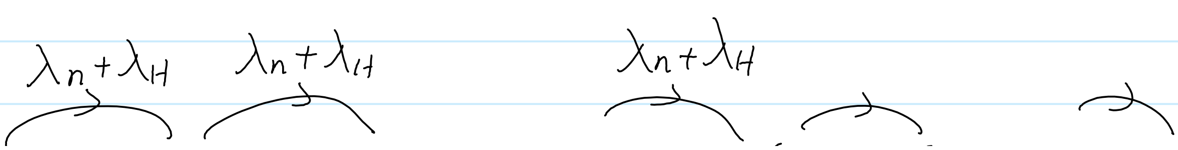
N : total # of channels
K : # of channels accessible by new calls
$K \le N$

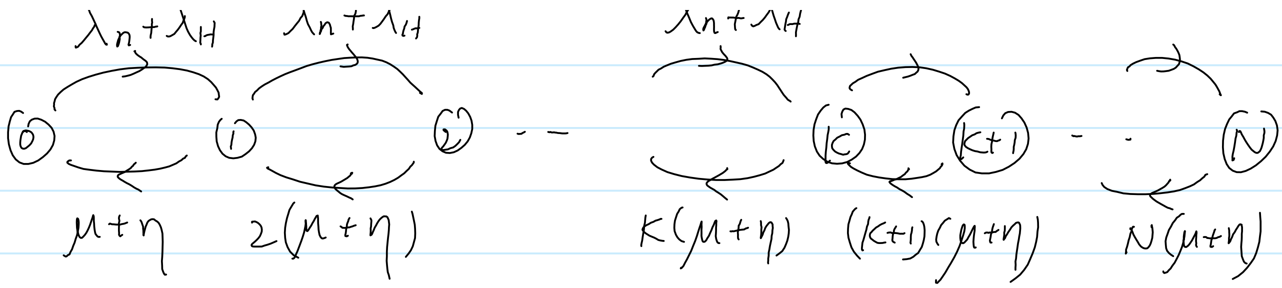
All channels can be accessed by handoff calls.

When $n < K$, both new calls & handoff calls are accepted.

When $K \le n < N$, only handoff calls are accepted

When $n = N$, neither new calls nor handoff calls are accepted.





Let $\Omega = \lambda_n + \lambda_H$

$\mu_c = \mu + \eta$

Write down the balance equations

$$\Rightarrow \quad P_n = \begin{cases} P_0 \left(\frac{\Omega}{\mu_c}\right)^n \frac{1}{n!} & \text{when } n \le K \\ P_0 \left(\frac{\Omega}{\mu_c}\right)^K \left(\frac{\lambda_H}{\mu_c}\right)^{n-K} \cdot \frac{1}{n!} & \text{when } n > K \end{cases}$$

Using $\sum_{n=0}^{N} P_n = 1$, solve P_0

$$P_0 = \frac{1}{\sum_{n=0}^{K} \left(\frac{\Omega}{\mu_c}\right)^n \frac{1}{n!} + \sum_{n=K+1}^{N} \left(\frac{\Omega}{\mu_c}\right)^K \left(\frac{\lambda_H}{\mu_c}\right)^{n-K} \cdot \frac{1}{n!}}$$

Prob. of handoff call blocking

$P_{BH} =$

Prob. of new call blocking

$p_{Bn} =$

Optimization - 5min

Friday, February 22, 2008 4:22 PM

What should K be?

Depends on what you want to optimize.

Example 1: maximize # of new calls

Given N, μ_c, λ_H

$$\max_K \quad \lambda_n$$

$$\text{sub to} \quad P_{Bn} \leq \eta_{max}$$
$$P_{BH} = H$$

Example 2: Minimize new call blocking

Given λ_n, N, μ_c, λ_H

$$\min_K \quad P_{Bn}$$

$$\text{sub to} \quad P_{BH} \leq H_{max}$$

Example 3: maximize revenue.

Given λ_n, N, μ_c, λ_H

$\max_{K} \ \gamma$ = average # of users in a cell

sub to $P_{BH} \le H_{max}$

Note: $\gamma = \sum_{n=1}^{N} n \cdot p_n$.

Alternatively, we can jointly solve for N & K

65

Dynamic channel allocation - 10min

Tuesday, February 26, 2008 12:40 PM

- This treatment of handoff calls can be seen as an example of the efficiency of dynamic channel management
- While this example was single-cell only, we can push this idea further to across cells

---

Note that so far we have focused on a fixed channel allocation (FCA) paradigm

⇒ channels are allocated permanently to each cell for its exclusive use.

- based on offered load and desired quality of service.

Hence, users in a cell can only be served by channels belonging to the cell. Even if idle channels are found elsewhere in the system (e.g. neighboring cells), they cannot be made use of.

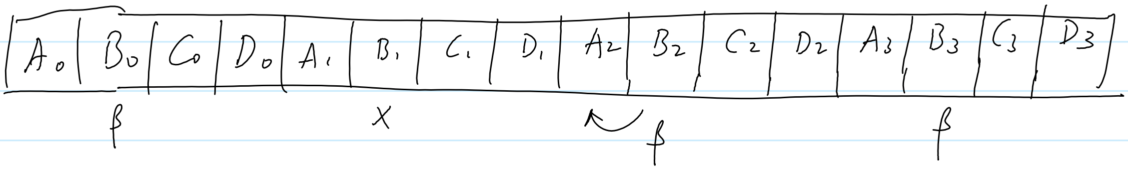
Advantage of FCA: Simple to implement
Disadvantage: Higher blocking probability
Lack of adaptivity when offered load changes

(Q) If there are no channels available in a cell, can one of the channels of the neighboring cells be used to accommodate the call?

(A) Yes, but needs to be careful.

Example: Channel borrowing

Consider the 1-dim scenario, where the reuse factor is 4. Normal FCA results into this pattern.



Suppose all channels in cell A_2 are in use, but there is a channel β available in cell B_2.

Let cell A_2 borrows the channel β from B_2.

Due to reuse constraints, cell B_1 cannot use channel β either

⇒ Channel β locked out of service in cell B_1

⇒ The usage of channel β is then separated over further distance than the normal reuse distance of 4 cells.

This is why we observe many DCA schemes have improved perf. (in terms blocking prob.) at low to medium loads, but degraded perf. at high loads.

Possible Solution:

- directional channel locking.

When A_2 borrows channel β from B_2,
cell B_1 cannot use channel β
C_1 cannot borrow β from B_1

but cell A_1 can borrow β from B_1.

- What if channels are not assigned to cells a priori at all?

⇒ Dynamic Channel Allocation

- In the extreme case (maximum packing), all channels can be reassigned every time a call arrives or departs.

In the literature, channel borrowing is categorized into FCA (although its dynamic in nature), and DCA is referred to schemes that do not pre-assign channels

A good survey article:

I. Katzela & M. Naghshineh, "Channel Assignment Schemes: A Comprehensive Survey," IEEE Personal Communication Magazine, Vol. 3, No. 3. June 1996, pp10-31.

10

Voice vs. Data -10min

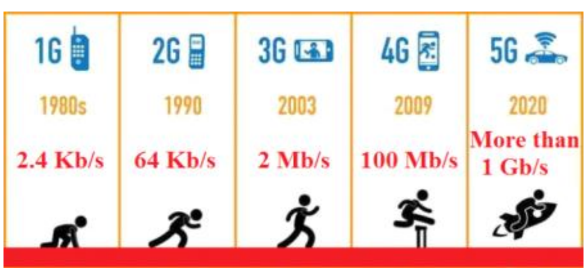
Saturday, January 27, 2018 10:24 AM

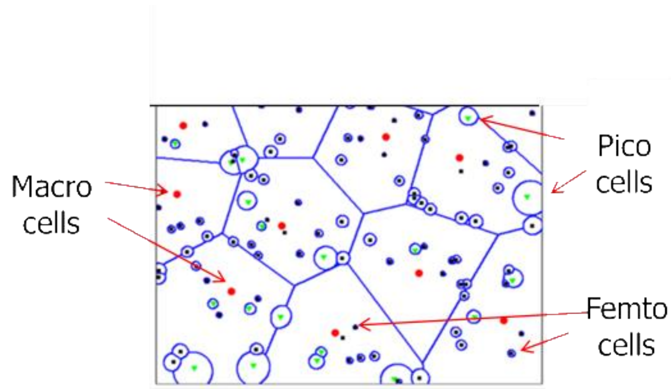
- So far the discussion has primarily focus on 2G voice systems.

- We will now move on to data systems (3G/4G/5G)

- We will see many differences in traffic characteristics and network topology, which will lead to different considereration for multiple access.

Voice	data
- circuit-based fixed, low rate	- packet-based variable, high rate
- regular cell patterns mostly single hop	- more ad hoc cell patterns can be multi-hop
- work against channel variations	- exploit channel variations





(Source: Prof. Jeffery Andrews, UT Austin)

Heterogeneous Cellular Networks

Multi-access: Co-Exist or Time-Share - 10min

Tuesday, April 08, 2008 12:27 AM

- Let us revisit the question of multiple access
- For voice, we have seen CDMA has an advantage due to statistical multiplexing. How about data?

(Q) How do two or more data users co-exist?

(A) Two approaches

TDMA/FDMA - oriented:

- users interleave their transmission
- Only one user transmits at a time (within one cell and within one freq channel)
- The active user sends at a high bit-rate per Hz

CDMA - oriented:

- use multiple codes to maintain a large # of concurrent transmissions.
- each user/channel sends at a lower bit-rate per Hz

We will see that for high data-rate services, TDMA/FDMA-oriented approach (i.e. scheduling one user at a time) is preferable.

Use an example:

- The Shannon capacity

$$B \log_2 (1 + SINR)$$

$$= B \log_2 \left(1 + \frac{P}{I+N}\right)$$

- Imagine two users in the same cell,

both use power P.

- TDMA: only one user transmits at a time.

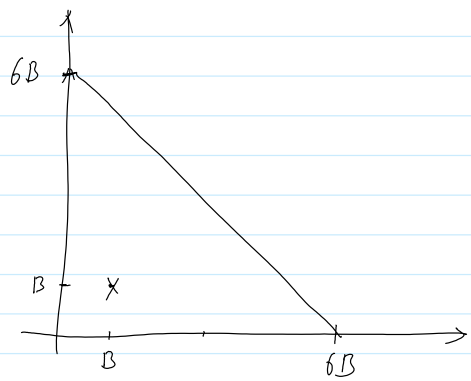
  - $C_1 = B \log_2 (1 + \frac{P}{N})$

  - At $P/N = 64 \Rightarrow C_1 = 6B$
    each user gets $3B$

- CDMA: Two users transmit together

  - $C_2 = B \log_2 (1 + \frac{P}{P+N})$

    $\approx B$



(Note that the processing gain cannot beat the Shannon capacity either.

With the processing gain w, the interference is lower to P/w, but the usable bandwidth for symbol demodulation is also reduced to B/w

$$\frac{B}{w} \log_2 \left(1 + \frac{P}{\frac{P}{w} + N}\right)$$
$$\leq B \log_2 \left(1 + \frac{P}{P+N}\right).$$

Time-interleaving (TDMA) may achieve much larger capacity region than simultaneous transmitting both traffic (CDMA).

This is why, even though all 3G standards use CDMA, they also switch to time-interleaving within a cell.

- CDMA is only used to suppress interference from other cells

In 4G, CDMA is completely abandoned.

- OFDM is used instead.

Why does the same conclusion not apply to voice?

- Voice is usually at a low, constant rate
- Voice requires stringent delay guarantees.

Adaptive modulation and coding (AMC)

- As the active user's channel condition changes, adaptive modulation & coding can be used to attain instantaneous rate close to

$$B \log\left(1+\frac{P}{N}\right).$$

  - e.g. when user is closer/further away from the base-station
- Such Adaptivity is achieved by:
  - Different processing gain
    - Earlier in CDMA, with a fixed chip rate $\frac{1}{T_c}$, we can use it for different symbol rate $\frac{1}{T_s}$
    - Higher symbol rate will lead to higher effective data rate
    - However,

      Higher $\frac{1}{T_s}$ $\rightarrow$ lower processing gain $W = \frac{T_c}{T_s}$.
      Since the demodulator needs a fixed effective SNR,

$$\frac{E_b}{I_0} = \frac{P}{\frac{I}{W}}$$

      It means that the raw SNR $\frac{P}{I}$ needs to be high
  - Different modulation: QAM, 16-QAM, 64-QAM
  - Different amount of error correction code.

- Finally, as the channels of multiple users vary in time & frequency, opportunistic scheduling becomes essential

Towards a general model for data systems - 10min

Thursday, January 17, 2008 4:14 PM

- Due to these differences, the previous design and analysis methodology for voice networks do not work any more
- We need a new model that allows us to capture
  - Variable data rates through AMC
  - ad hoc or even multi-hop topology
  - Opportunis scheduling

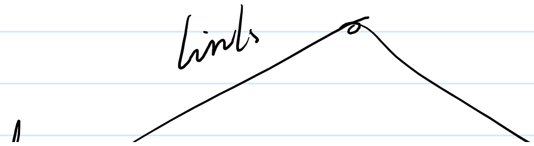
Consider a wireless ad hoc network with n nodes (BS, mobile, relay)

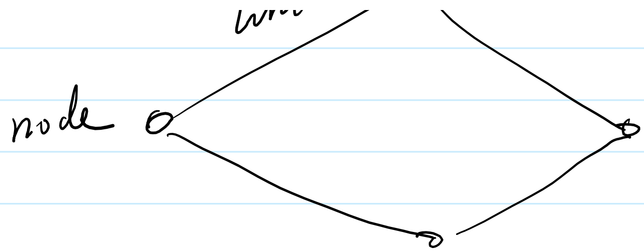
Define a link to be a transmitter - receiver pair

- L links.

In general, packets can traverse multiple hops wirelessly from the source to destination.

Some nodes may be connected to wired network.





Assume for the moment that the node locations are fixed.

Such a scenario can occur in many settings

- wireless mesh networks
  wireless sensor networks (e.g. for IoT)

As we will see soon, what we really need is that the "link" relationship is fixed.

- Cellular / Wireless LAN becomes a special case, provided that users do not change cells

The channel between transmitter/receiver can experience time-varying fading.

Multitude of design problems

① What is the transmission power and rate that each link should use at each time?

(2) How to regulate multiple access?

- Should nodes transmit simultaneously or interleaved in time/freq
- Which set of links should be active at each time

→ Link scheduling problem.

(3) How to find routes?

- important for ad hoc network
- May not applicable for cellular/wireless LAN

(4) How to make sure that the users received the level of service requested?

- rate
- delay
- loss
- fairness
- energy conservation

We will formulate these questions somewhat independently from the specific technology.

Other remarks

(1) We assume that data are decoded at the receiving end of each link

- decode - store - and forward.

Alternately, the intermediate node can directly amplify the received signal and let the destination node decode it directly

- amplify - forward cooperative relaying
- information theoretic.

(2) We do not handle the question of mobility, i.e, when links come & go.

- No handoff.

Still, these form a difficult set of problems. Compared to wireline networks

- Links no longer have fixed capacity
- Highly dependent on the physical layer
  - Transmission signal strength
  - Interference levels
  - Coding / Modulation / Multi-access
  - channel fading
- Power remains a crucial constraint.

(30)