Lecture Notes 6/29/2016

Medium Access.

Randomized Access
- slotted Aloha
- CSMA

Scheduled Access
- TDMA
- Channelized protocols

Slotted Aloha: max throughput $p^* = \frac{1}{n} \rightarrow \frac{1}{e}$

$\sim 36-37\%$

throughput regions if multiple users w/ different access probabilities

at the boundary $\sum p_i^* = 1$

$T_i = p_i \prod_{j \neq i} (1-p_j)$

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CSMA : p-CSMA ← p-persistent CSMA

contention slots $\delta \leq T_c \leq T_s$

$$\text{Throughput} = \frac{T_s n p (1-p)^{n-1}}{\delta \cdot (1-p)^n + T_s n p (1-p)^{n-1} + T_c \left(1 - (1-p)^n - np(1-p)^{n-1}\right)}$$

802.11 CSMA → FSM describing the backoff stage & counter value

modelled as a Markov Chain

derive steady state probabilities

approximate as p-CSMA.

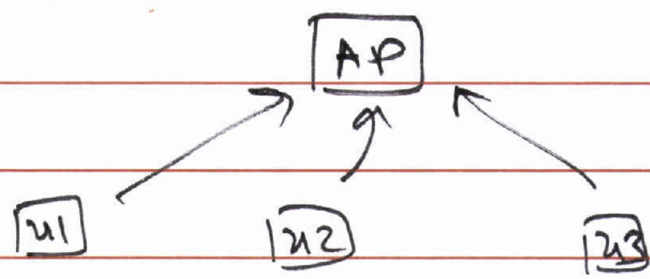
for larger packets CSMA throughput can be high 90% or more.

RACH channel in Cellular networks — control signalling channel — basically slotted Aloha

Scheduled access.
channelized systems

Channel : - Time
- Frequency
- codes (CDMA)

orthogonal dimensions (ideally) => no interference.

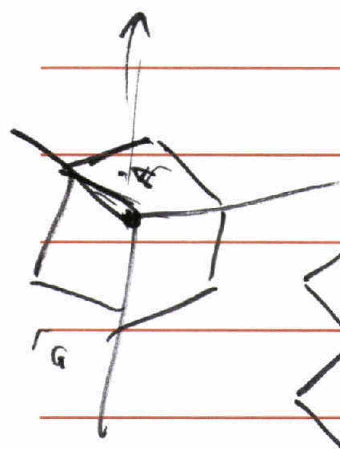


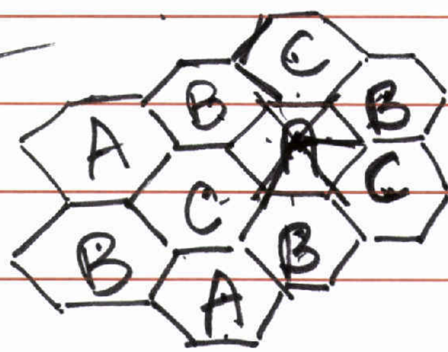
with synchronization, nodes can be preallocated a time slot.

Many applications, e.g. industrial sensing, have predictable, periodic traffic.

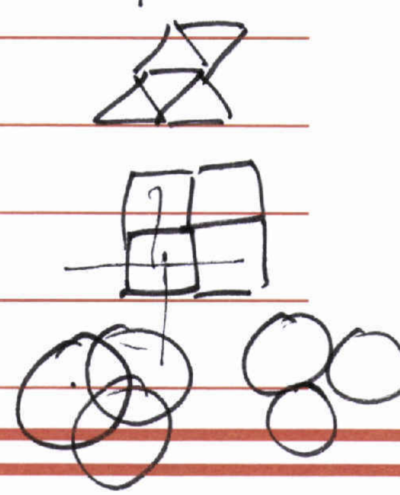
Another example: AMR

Classic <u>Cellular</u> (<u>Ideal</u>)

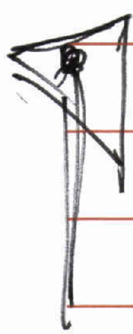


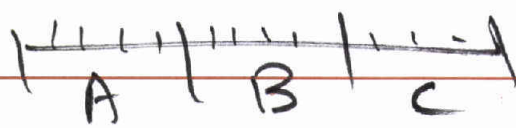


· Tessellation
· Equidistant



Frequency Reuse.

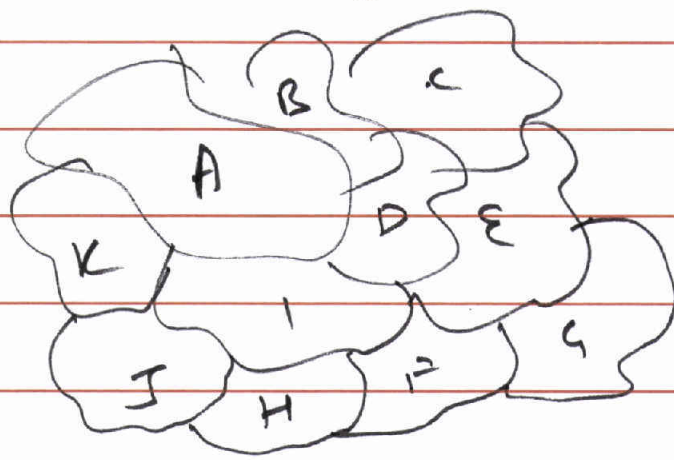




ensure that neighbor cells don't have the same channels, but "far away" cells can reuse frequencies.

multi-sector cellular

An Arbitrary cellular system

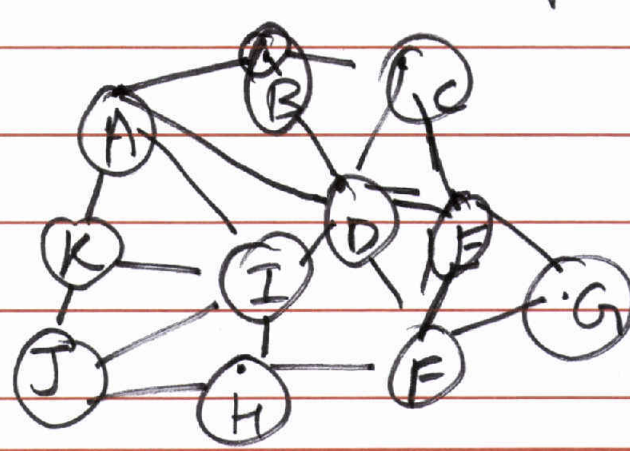


model the interference structure as a Graph.

$G = (V, E)$

cells $\Longleftrightarrow$ vertices

interfering cells have an edge between them.



1. how many "chunks" should the spectrum be divided into?
2. which chunk to allocate to which cell to ensure neighboring cells do not interfere?

Well known problem in Graph Theory:
Vertex Coloring
(Graph Coloring)

Try to allocate a set of colors, one to each node/vertex, so that no two vertices sharing an edge have the same color, + minimize the number of colors used.

fewer "chunks" => more spectrum per cell => more capacity/users per cell.

This problem (vertex coloring)
is NP-Hard.

Some problems such as
shortest path routing can
be solved exactly in
time that scales polynomially
in the problem size:

e.g. Dijkstra's takes $O(|V|^2)$
w/ a simple implementation

$\sim O(|E| + |V|\log|V|)$
more clever implementation

These problems are considered
to be tractable or efficiently
solvable.

said to be in the class P

For other problems, such as the longest-path motif problem, there are no known polynomial-time algorithms.

(~~to~~ instead exact algorithms take exponential ~~time~~ time:

$O(2^{|V|})$

These problems are called NP-Hard.

⇒ cannot guarantee exact solution quickly always.

For many practical problems, can use heuristics that are fast, and often give exact optimal **OR** near-optimal solutions.

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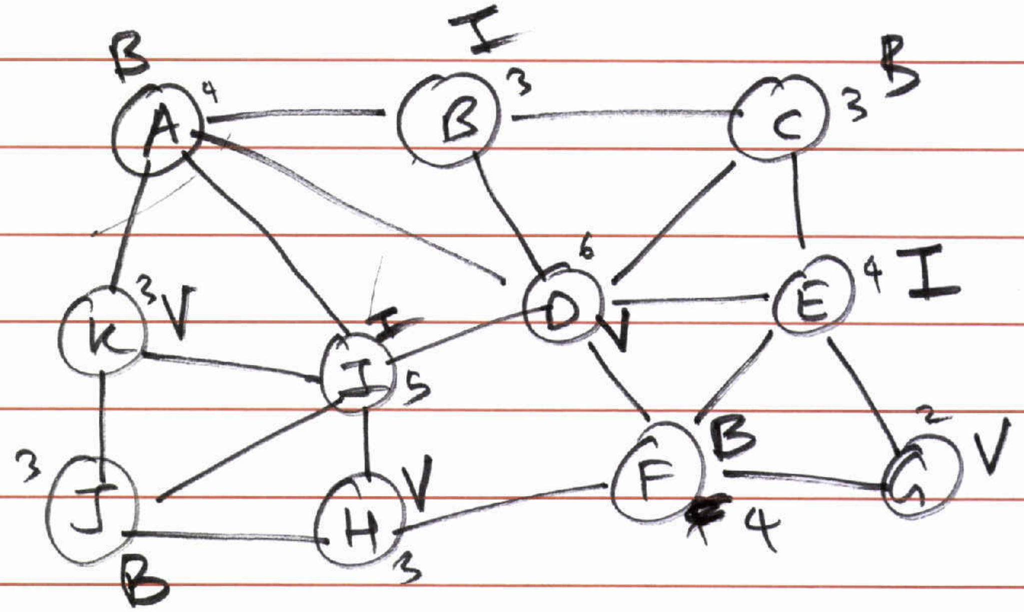
A Heuristic algorithm for Graph Vertex Coloring:

Greedy Vertex Degree Ordering (GVDO) heuristic:

1. Sort vertices in decreasing order of their degree (i.e # of neighboring vertices)

2. From the top of this list, assign the earliest possible color (reusing it possible) that does not violate the edge constraint



D I A E F B C H J K G

only 3 colors needed!

the optimal number of colors needed is called the chromatic number of a graph

$\chi(G)$.

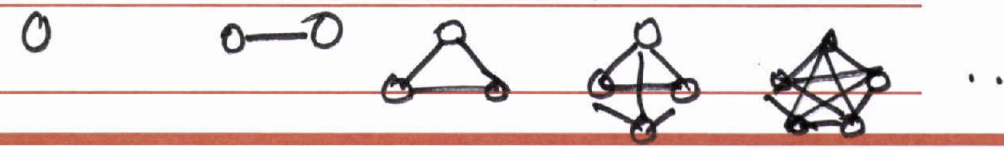
Violet
Indigo
Blue
Green
Yellow
orange
Red
⋮

max degree of graph

$$\psi(G) \leq \chi(G) \leq \underset{\text{max}}{\Delta}(G)+1$$

maximum <u>clique</u> size of graph.

Clique: a subset of vertices that are all connected to eachother.



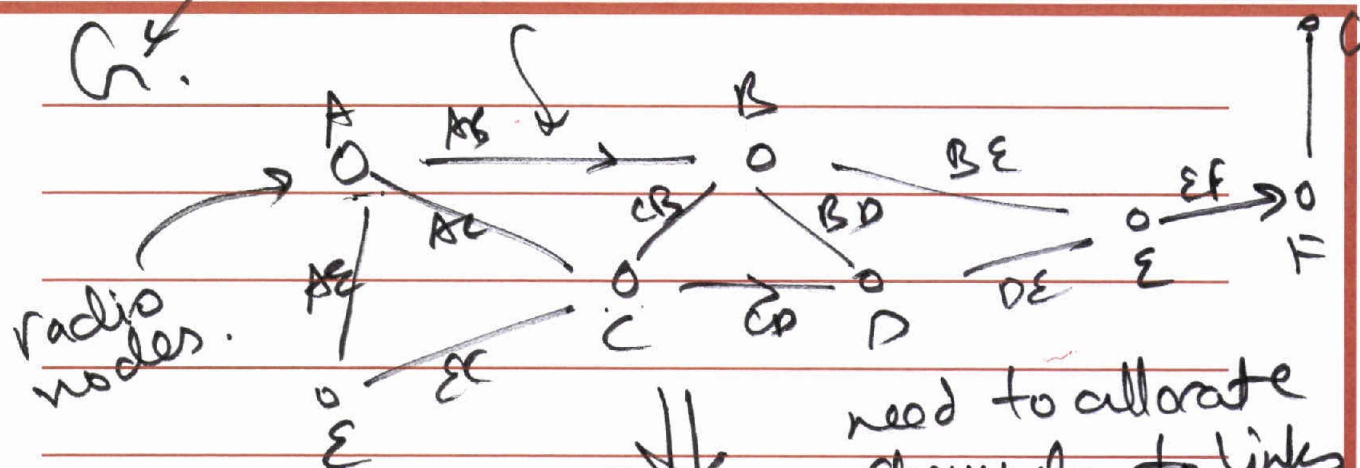
Can show that GVDO never needs more than $\Delta(G)+1$ colors

(may be a loose bound).

Can apply graph coloring for allocating channels to links in multi-hop wireless networks such as low power IoT networks / mobile ad-hoc networks / wireless mesh networks.

Communication graph · wireless comm links

G



need to allocate channels to links s.t. links that interfere are given different channels

Conflict Graph

H

Conflict Graph

node of H $\Longleftrightarrow$ link in G

edges of H $\Longleftrightarrow$ pairs of links that cannot be operated on same channel

Vertex coloring on H $\Rightarrow$ Can use GVDO for this

gives us the desired channel allocation on G.

fewer channels $\Rightarrow$ higher throughput / capacity per link.