LOCAL AREA NETWORKS

Unlike Satellite systems (prev lecture), the round-trip delay for LANs is a small fraction of the packet duration, and hence reservations can be made for immediate future. A number of nodes are connected onto a common cable; when one node transmits a packet, all other nodes listen to it. A node can simultaneously listen and transmit, and a collision can be detected shortly in case two or more nodes transmit almost simultaneously. This technique is called CSMA/CD (Carrier Sensing Multiple Access/ Collision Detection).

Slotted CSMA/CD

Ethernet is visualized in terms of slots and mini-slots. The mini-slots are of duration $\beta$, where $\beta$ = Fraction of slot to detect whether the channel is idle or not. If all nodes are synchronized, and if only one node transmits, all other nodes will get to detect the transmission in $\beta$, and will not use subsequent mini-slots till the entire packet is completed. Following the same drift analysis as in Slotted Aloha, the number of nodes transmitting after an idle slot is POISSON with parameter

$$g(n) = \lambda \beta + q_r n$$

where

- $\lambda$ = Arrival Rate
- $\beta$ = Mini-Slot for carrier sensing
- $q_r$ = Probability with which a backlogged node transmits after an idle slot, and
- $n$ = Number of backlogged nodes

Consider the following cases:
1. No transmission occurs: The next idle slot ends after $\beta$,
2. One transmission occurs: The next idle slot ends after $(1 + \beta)$, where '1' is the expected packet duration
3. Collision occurs: The next idle slot ends after $2 \beta = (\beta + \beta)$, where the second ' $\beta$ ' is part of the scheme so that all nodes hear an idle slot after the collision to make sure that it is safe to transmit. Note that this value of ' $2 \beta$ ' is different than the corresponding value for CSMA

Assigning probabilities to these values, we have, for $k = \#$ of successful packets,

<table>
<thead>
<tr>
<th>Condition</th>
<th>$k$</th>
<th>Interval = $T$</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>0</td>
<td>$\beta$</td>
<td>$e^{-g}$</td>
</tr>
<tr>
<td>Success</td>
<td>1</td>
<td>$1 + \beta$</td>
<td>$ge^{-g}$</td>
</tr>
<tr>
<td>Collision</td>
<td>0</td>
<td>$2 \beta$</td>
<td>$1 - (e^{-g} + ge^{-g})$</td>
</tr>
</tbody>
</table>
which gives,

\[ E[k] = 0 \cdot e^{-g} + 1 \cdot ge^{-g} + 0 \cdot \{1-(e^{-g} + ge^{-g})\} = ge^{-g}, \] and
\[ E[T] = \beta \cdot e^{-g} + (1+\beta) \cdot ge^{-g} + 2 \beta \cdot \{1-(e^{-g} + ge^{-g})\} \]
\[ = \beta + ge^{-g} + \beta \cdot \{1-(1+g) e^{-g}\} \]

Note that 'g' is actually 'g(n)' in all the above formulae.

\[ \lambda = \frac{E[k]}{E[T]} = \frac{ge^{-g}}{\beta + ge^{-g} + \beta \cdot \{1-(1+g) e^{-g}\}} \]

is maximized over g(n) at g(n) = 0.77, and the resulting value of \(\lambda\) is

\[ \lambda = \frac{1}{1+3.31 \beta} \]

----- Equation A (4.66 in Text)

which is a better throughput than for CSMA/FCFS, for which the value was

\[ \lambda = \frac{1}{1+\sqrt{2\beta}} \]

For more on Slotted CSMA/CD, please refer to the text (pg 318)

**Unslotted CSMA/CD**

The constant (3.31) in Equation A, is dependent on detailed assumptions, and is different for different assumptions. However, if \(\beta\) is very small (like in Ethernet), this value is not very important. Unslotted CSMA/CD is difficult to analyze because it is not synchronized on the \(\beta\) mini-slots, and collision by nodes that are closer together is faster than those more spread around. Suppose a node on the LAN starts to transmit, and \(\beta\) time units later, another node starts. The second node ceases its transmission immediately after hearing the first one, but still causes errors in the first packet and forces the first node to stop transmission. Another \(\beta\) time units go by till the second comes to know that the first one has stopped. The diagram illustrates the phenomenon:

Analysis (Ref pg. 319 text) leads to the evaluation that
\lambda = 1 / [ 1 + 6.2 \beta ] \quad \text{----- Equation B (equivalent to 4.69 in Text)}

Reason for having $\sqrt{\beta}$ in CSMA and constant* $\beta$ in CSMA/CD

Collisions are not very costly with CSMA/CD, and thus much higher attempt rates can be used. For the same reason, immediate transmission works well with CSMA/CD but poorly for CSMA.

WWW Links
Here are a few links to some useful links:

5. Lecture on LAN System Technology at ([http://www.anritsu.co.jp/plaza_e/lansys2.html](http://www.anritsu.co.jp/plaza_e/lansys2.html))

Token Rings
Nodes are arranged logically in a ring, with each node transmitting to the next node around the ring. Each node relays the bit stream from the previous node to the next one. There is at least a bit delay so that the node gets time to read the bit before sending it onto the next node. When a node has to transmit, it must discard what is being received. And to make sure that something is not discarded before it has been read, the entire cycle is terminated on the initiator of the packet. This initiator holds a 'TOKEN', which it releases to the next node once it is done with its transmissions.

The arc gives the path a data stream will take till it gets its destination. The dotted line shows the path of the token stream as it terminates on the initiator, and hence makes it give away the
token. The properties of a token are the same as those of the 01^1 flags we studied in DLC (Sec 2.5.2 pg. 88). The token is passed to the next node by placing an idle token 01^0 at the end of the data stream. If the next node needs to take control of the token, it changes the flag from 01^0 to 01^1 (by toggling the last bit). If it does not need the control, it simply passes the token. So, the data flows in a token ring as:

<table>
<thead>
<tr>
<th>BUSY TOKEN</th>
<th>ADDR. of NODE + DATA</th>
<th>IDLE TOKEN</th>
</tr>
</thead>
</table>

More about Token Rings from the text (Section 4.5.3 pg. 320…) and from the web from [Token Ring](http://www.whatis.com/tokenrin.htm).

**Distributed Queue Dual Bus (DQDB)**

DQDB is a high speed LAN architecture, in which each node is connected to two unidirectional 150 Mbps (optical fibers) buses going in opposite directions. A node uses the right moving bus to send frames to the right, and the left moving bus to send frames to the left.

Fairness is introduced into the architecture by introducing a request bit, which a node sends in the opposite direction of where it intends to send the data. More about the scheme can be known from the text (pg. 335)

**PACKET RADIO NETWORKS**

Every node in a Packet Radio Networks is in the reception range of some subset of other nodes. Thus:
- If only one node in the subset is transmitting, then that node can receive the transmission
- If multiple nodes are transmitting simultaneously in the same band, then the reception is garbled.
- What one node transmits will be received by a subset of other nodes.
• A subset of nodes to which a given node can transmit is different from the subset of nodes from which it can receive.

An example of Packet Radio Network is an Ad-Hoc Mobile Network. There are no base stations, and hence no central call/data switching entity. There is no concept of call admission, where the Base station would have assigned a frequency and/or timeslot to the mobile for its uplink and downlink transmission. In AdHoc networks, Mobile Terminals (MT) may need to act as switches, by storing and forwarding packets to the target MT.

The topology of a radio network can be defined by a simple model, which assumes that every MT transmits with a fixed power. This defines a transmission radius around each MT. The topology is defined by a graph $G = (N, L)$, which contains a set of nodes $N$, and a set of links $L$. Each link in $L$ corresponds to an ordered pair of nodes $(i, j)$, and indicates that transmissions from node $i$ can be heard at node $j$. A packet from node $i$ will be received correctly at node $j$ iff,

1. $(i, j) \in L$
2. No other node $k$, from which $(k, j) \in L$, is transmitting at the same time
3. $j$ itself is not transmitting at the same time

A large number of links in the graph is not desirable. Natural environmental barriers cause the number of ordered pairs in the links to reduce, which simplifies the problem of calculating how much traffic these AdHoc networks can carry.

A Collision Free set is defined as a set of links that can carry packets simultaneously, with no collisions at the receiving end. For e.g. $\{(1,2), (5,6)\}$ and $\{(2,1),(6,5)\}$ are both collision free sets. These links are ordered in some arbitrary order, where each collision free set is represented as a vector called Collision Free Vector. Some of the CFVs are listed below:

<table>
<thead>
<tr>
<th>(1,2)</th>
<th>(2,1)</th>
<th>(2,3)</th>
<th>(3,2)</th>
<th>(3,4)</th>
<th>(4,3)</th>
<th>(3,5)</th>
<th>(5,3)</th>
<th>(5,6)</th>
<th>(6,5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>1</td>
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<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
In a CFV \( \mathbf{X} \) (vector), if \( X_l = 1 \), that implies that link \( l \) can transmit for the CFV. For a set of CFVs \( \{ X_1, X_2, X_3, \ldots, X_J \} \) (a set of \( J \) CFVs), the vector \( \mathbf{f} \) gives the fraction of time each link can be used

\[
f = \frac{1}{J} \sum_{j=0}^{J} X_j
\]

and \( f_l \) is fraction of time link \( l \) can be used.

For more on fractional utilization of each link, please refer to the text (Sec. 4.6.1 pg 346)