New-Mechanisms for Improving the Performance of TCP over Wireless Links

1) Freeze-TCP by T. Goff, J. Moronski
   End-to-End solution. Discussed in the seminar. The receiver advertises a zero-window during the handoff period and the sender enters retransmit timer until it receives three DACKs or non-zero advertised window. Problems occur when the handoff lasts longer than the time-out of TCP.

2) Probing Devices by V. Tsoussidis and A. Lahanas (Northeastern University)
   End-to-End solution. When loss is detected by the sender, TCP starts probing cycle to detect the nature of the error and its termination. TCP backs off only if the error is caused by congested links.

3) Syndrome by W. Chen and J. Hou (Ohio State University)
   Intermediate solution with support from the Base Station. The Base Station is attaching a number at the option field of TCP. Based on this number the receiver can notify the sender for the cause of the error.

Probing Devices

- TCP detects errors by a 3-DACK event or a Time-out. After these events the threshold value is set to half the value of congestion window and TCP recovers with Fast-Recovery or Slow Start.

- What is the probing mechanism?
  - TCP headers (Probing Segments) without pay-load send by the sender and acknowledged by the receiver.
  - Probing Flags are inserted at the options field to distinguish different probing segments.
  - Acknowledgment of probing segments send by the sender completes a Probing Cycle.
  - At least two cycles are required to complete a Probing Cycle.
  - Probing Flags are: PROBE1, PROBE2, PROBE1_ACK, PROBE2_ACK
  - TCP measures the time (Probing-RTT) needed to complete each probe cycle.
  - TCP measures the best RTT.

- Probing Cycle is initiated every 3-DACK event or Time-out event
  - Congestion Window and Threshold value are saved before initiation of the Probing Cycle.

Probing Devices (cont)

- Recovery of TCP with probing mechanisms (TCP-Probing)
  - Immediate Recovery
  - Fast Recovery
  - Slow Start

- TCP-Probing State Diagram
**Probing Devices (cont)**

- **Immediate Recovery**
  - Performed when the Probing-RTTs are better than the best RTT.
  - Time-out event: Threshold is set to the value of congestion window before the Probing Cycle.
  - 3-DACK event: Congestion Window is set to its value before the congestion.

- **Fast Recovery**
  - Performed when the Probing-RTT measured during the second probing cycle is better than the best RTT
  - Time-out event: Slow Start is applied.
  - 3-DACK event: Congestion Window is set to half of its value before the congestion.

- **Slow Start**
  - Performed when the Probing-RTTs are bigger than the best RTT
  - Time-out event: Slow Start is applied.
  - 3-DACK event: Slow Start is applied.

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**Syndrome Approach**

- **Approach**: Intermediate Solution. Requires Intervention at the Base Station.
  - The Base Station counts the packets of the TCP flow and attaches the counter at TCP header option field.
  - *Syndrome* (positive gaps in TCP Sequence Numbers and Attached Sequence Numbers) is computed at the receiver.
  - Gaps at the Attached Sequence numbers mean errors at the wireless portion of the network.
  - Receiver sets the ELN bit at the TCP header of the ACK
  - ELN bit is interpreted as link error and the sender doesn’t back off.

- **Pros**
  - Better than Split Connection approach.
  - Better than the Snoop approach
  - Limited resources at the Base Stations.

- **Cons**
  - Cannot handle loss caused during handoff periods - Time-outs.
  - Due to mobility the Base Station process must be transferred at the new Base Station.
  - Assumption that ACKs always arrive at the sender.

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**Example**

<table>
<thead>
<tr>
<th>Sequence Number</th>
<th>Attached Number</th>
<th>Max SN Seen</th>
<th>SN in ACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap of 1</td>
<td>11</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>14</td>
<td>12</td>
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<tr>
<td>15</td>
<td>4</td>
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<td>12</td>
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<tr>
<td></td>
<td>16</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>No Gap. &lt; 0</td>
<td>12</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>No Gap. Max seq seen is 16</td>
<td>17</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>8</td>
<td>18</td>
</tr>
</tbody>
</table>