Random access procedure capacity evaluation in LTE-A

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27, March 2015
Outline

1. Context & problem statement
   - Access capacity of a cell
   - Slotted aloha

2. Contention-based random access: 4-steps procedure

3. Collision scenario

4. Access capacity evaluation
   - Assumptions & parameters
   - Results & discussion

5. Perspectives
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Targeted environment

- Dense cells
- Small packets
  - Smartphones
  - MTC i.e sensors of smart-* environment

Access capacity of a Cell?
Network access metrics

- **Access Capacity:**
  - Number of successful simultaneous access
  - Unit = number of successful access request/period

- **Blocking probability**
  - Number of failed request access

- **Access delay**
1st random access protocol

Satellite system, wireless..

Principle:

- When a node has a packet to send, it waits until the beginning of the next slot.
- If no other nodes attempt transmission during that slot, the transmission is successful.
- Otherwise, Collision.
- Collided packet are retransmitted after a random delay.

Capacity evaluation in term of throughput
Access management techniques
Always Aloha for cellular networks access

- Core of the access process in cellular networks
- Freedom degrees:
  - Contention space
  - Resources
- Idea: decrease message length
  - Aloha: Full message
  - CSMA/CA: RTS/CTS
  - LTE: preambles
- Limit: ability to distinguish users
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step1: Slotted-Aloha + preamble

- **Step 1**: Send Preamble: 1 bit info about msg 3 size on PRACH
Step 2: transmission of random access response

Step 1:
- UE sends Preamble: 1 bit info about msg 3 size
- On PRACH

Step 2:
- Base station sends RAR (Random Access Response): Assign temp C-RNTI, UL grant for msg3, timing adjustment
- On PDSCH/PDCCH
Step 3: transmission of message 3

Step 1:
- Send Preamble: 1 bit info about msg 3 size on PRACH
- Send RAR (Random Access Response): Assign temp C-RNTI, UL grant for msg3, timing adjustment on PDSCH/PDCCH

Step 2:
- On PUSCH

Step 3:
- Send RA msg on the UL resource granted
Step 4: Contention resolution

1. **Step 1**: Send Preamble: 1 bit info about msg 3 size on PRACH.
2. **Step 2**: Send RAR (Random Access Response): Assign temp C-RNTI, UL grant for msg3, timing adjustment on PDSCH/PDCCH.
3. **Step 3**: Send RA msg on the UL resource granted on PUSCH.
4. **Step 4**: Contention resolution on PDSCH.
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Cell view point

Contest & problem statement
Contestation-based random access: 4-steps procedure
Collision scenario
Access capacity evaluation
Perspectives
User view point

1. **Packet arrival**
2. **Backoff counter = 0?**
   - If yes, go to **Transmission mode**
   - If no, go to **Backlogged mode**
3. **Collision**
   - If yes, go to **Transmission deferral**
4. **Max retransmission value reached?**
   - If yes, go to **Success**
   - If no, go to **Backlogged mode**
5. **Detection by eNB + No collision**
   - Go to **Success**
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Network level model

- **Perspective**
  - Cell view point

- **Parameters impact**
  - Number of available preamble for contention-based access
  - Frequency of Random Access slots

- **Performance metric**
  - Success ratio
Assumptions & parameters

- Periodic traffic
- One packet arrival per period
- Packets are independent and identically distributed over a period
- A user is either in:
  - Transmission mode (T-mode)
  - Idle mode (I-mode)
  - Backlogged mode (B-mode)
- No radio propagation model integrated
  - Transmission failure due to bad radio propagation: simulation input parameter
### Model parameters

<table>
<thead>
<tr>
<th>Notation</th>
<th>parameter</th>
<th>default setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_d$</td>
<td>detection probability of preamble transmission</td>
<td>0.95</td>
</tr>
<tr>
<td>$P_c$</td>
<td>collision probability of message3 transmission</td>
<td>0.2</td>
</tr>
<tr>
<td>$P_r$</td>
<td>reception probability on message3 transmission</td>
<td>0.9</td>
</tr>
<tr>
<td>$\text{backoff}_{\text{max}}$</td>
<td>maximum value of backoff window</td>
<td>5</td>
</tr>
<tr>
<td>$\text{max}_{\text{retransmit}}$</td>
<td>number of allowed retransmissions</td>
<td>5</td>
</tr>
<tr>
<td>$\text{opp}_{\text{period}}$</td>
<td>number of opportunities per period</td>
<td>50</td>
</tr>
<tr>
<td>$K$</td>
<td>number of available preambles</td>
<td>48</td>
</tr>
</tbody>
</table>

Table: Parameter setting
Model parameters (cont’d)

**Figure :** Detection probability impact on success ratio

**Figure :** Collision probability impact on success ratio

**Figure :** Reception probability impact on success ratio
Figure: Impact of number of available preambles on success ratio
Figure: Impact of number of opportunities per period on success ratio
Figure: Minimum required preambles for supporting new arrivals per opportunity
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### Short-term perspectives

- Access capacity share between different user types (H2H - MTC)
  - User point simulation
  - Distribution of # of retrials
  - Access delay

### Medium to long perspectives

- MTC grouped access
  - Gathering data to group heads
  - Access performed only by group heads
  - Group by application, localization..?

- Virtualization of devices access
  - Specially for V2I, MTC applications
  - 1 C-RNTI per application (instead of 1 C-RNTI per device)
Questions?