Defending Concealedness in IEEE 802.11n

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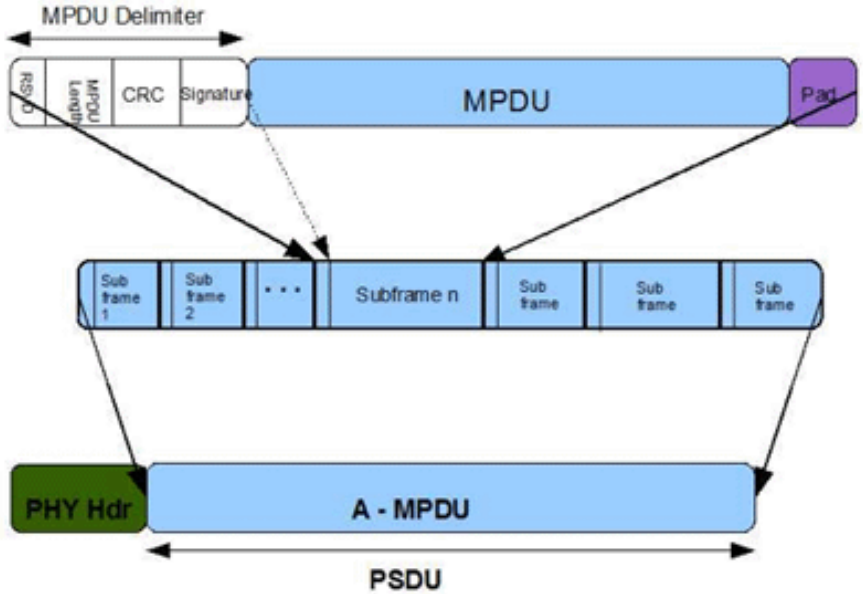
[2]Supported by COMSNETS 2014 Travel Grant

Preface: IEEE 802.11n

- High speed extension for wireless networks: 600 Mbps
- Extensions over IEEE 802.11b/g
  - MIMO - Spatial diversity and spatial multiplexing
  - Channel Bonding: Combine two 20 MHz channels to one 40 MHz channel (also knowm as 20/40 semantics)
  - MAC Layer: Frame aggregation and block acknowledgements



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IEEE 802.11 Channel Access

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- Two-way handshaking (Basic Access)

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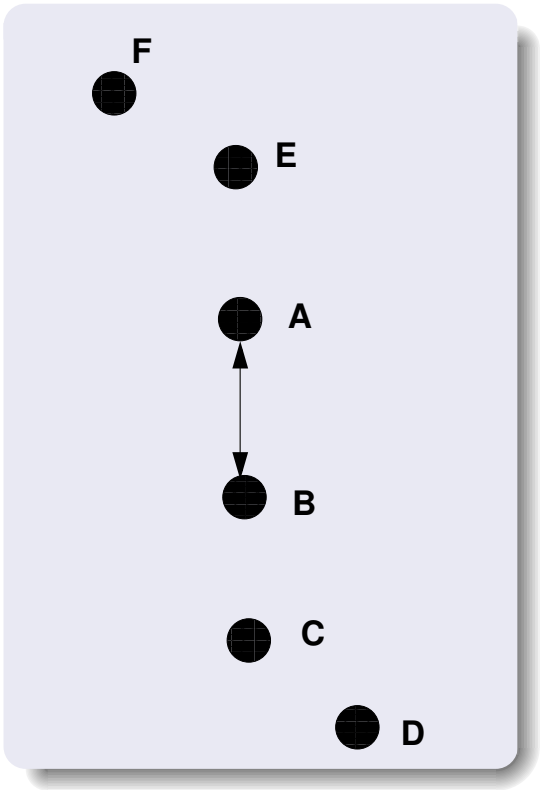

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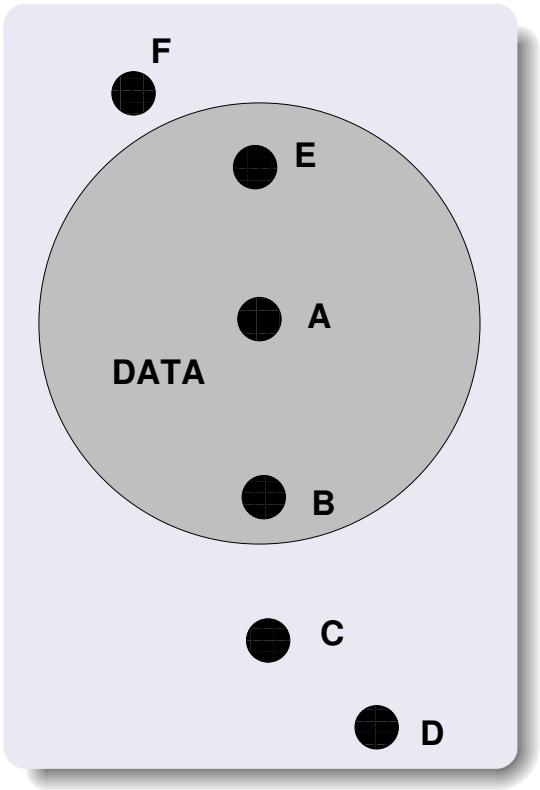

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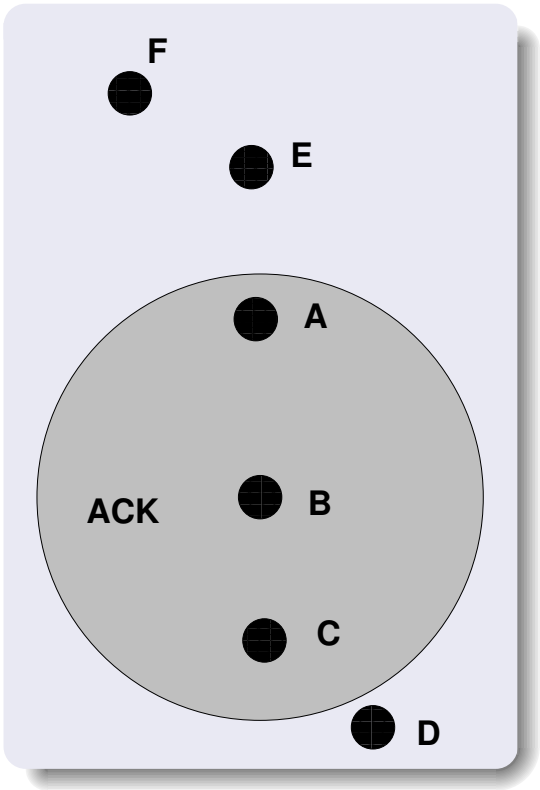

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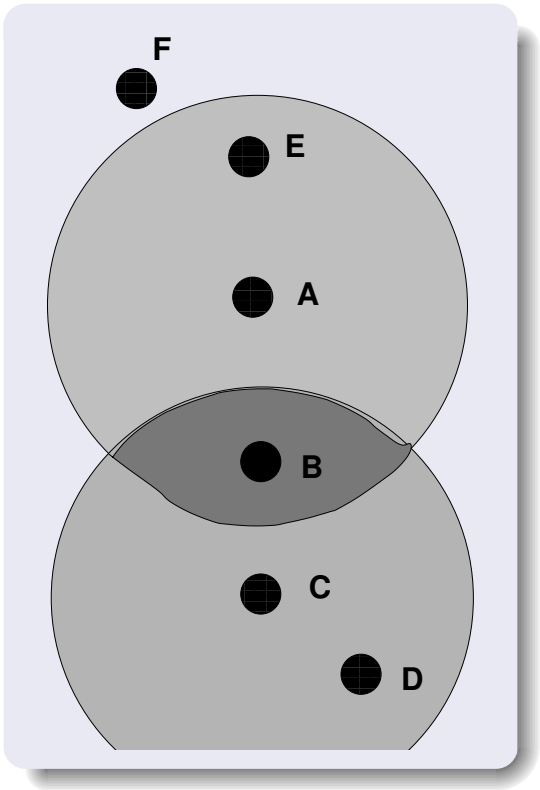

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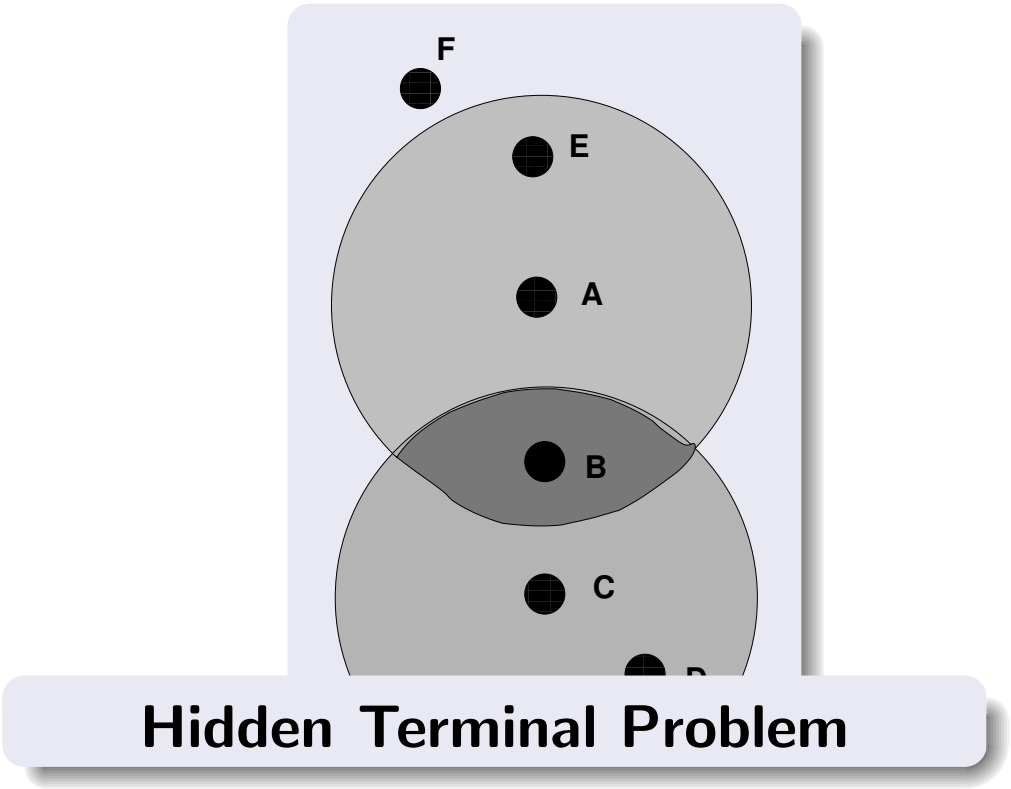

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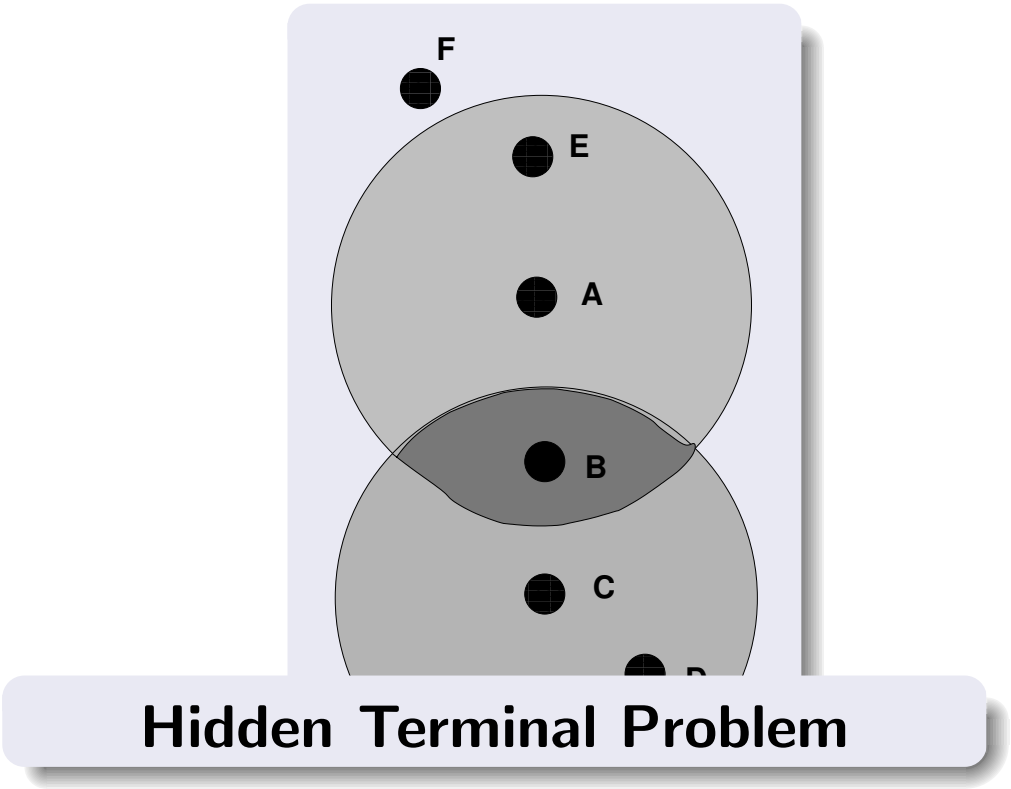

- Four-way Handshake (RTS-CTS Access)

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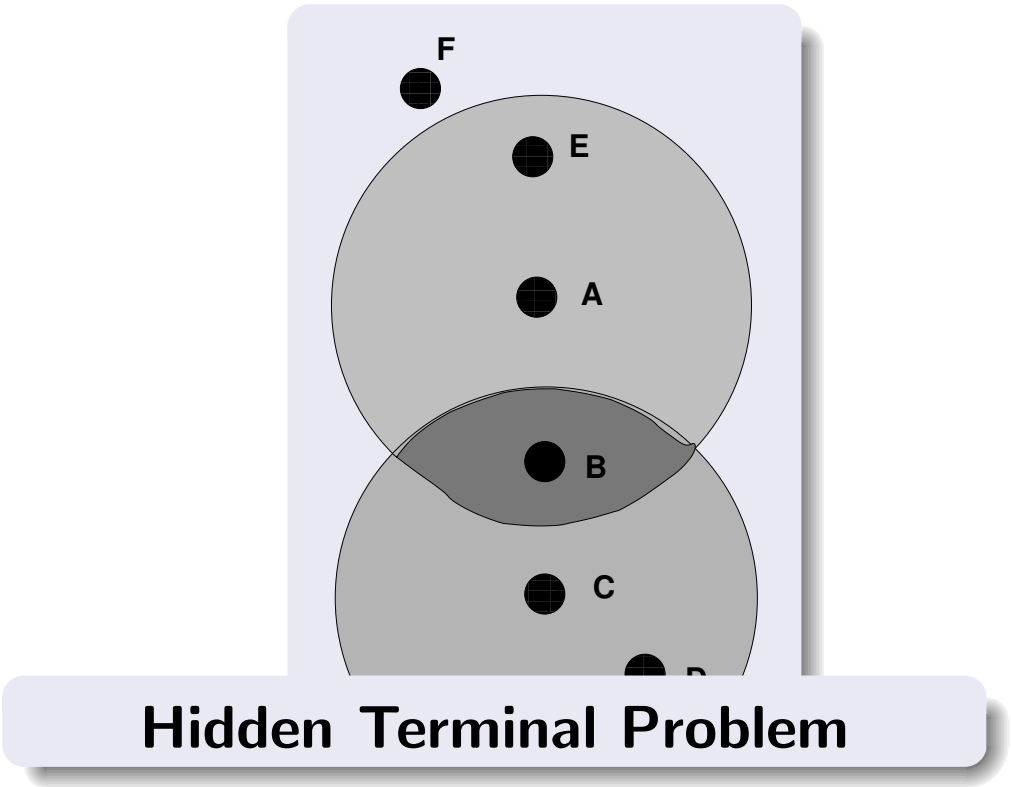

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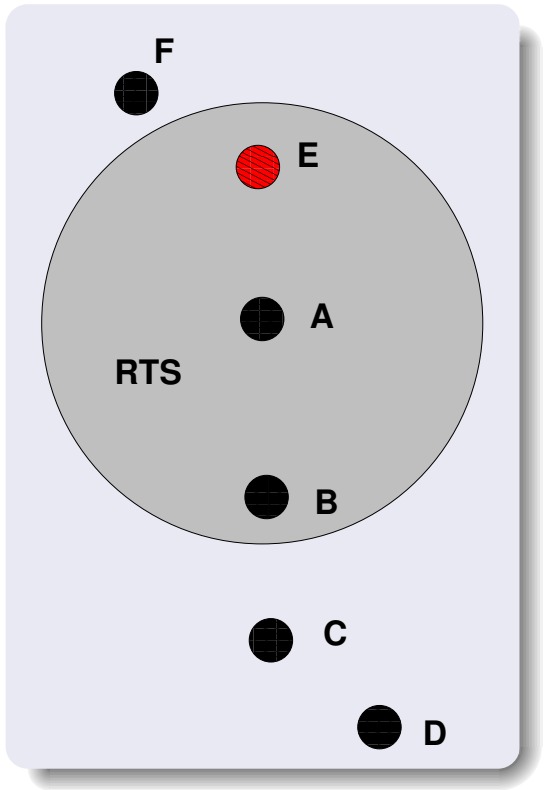

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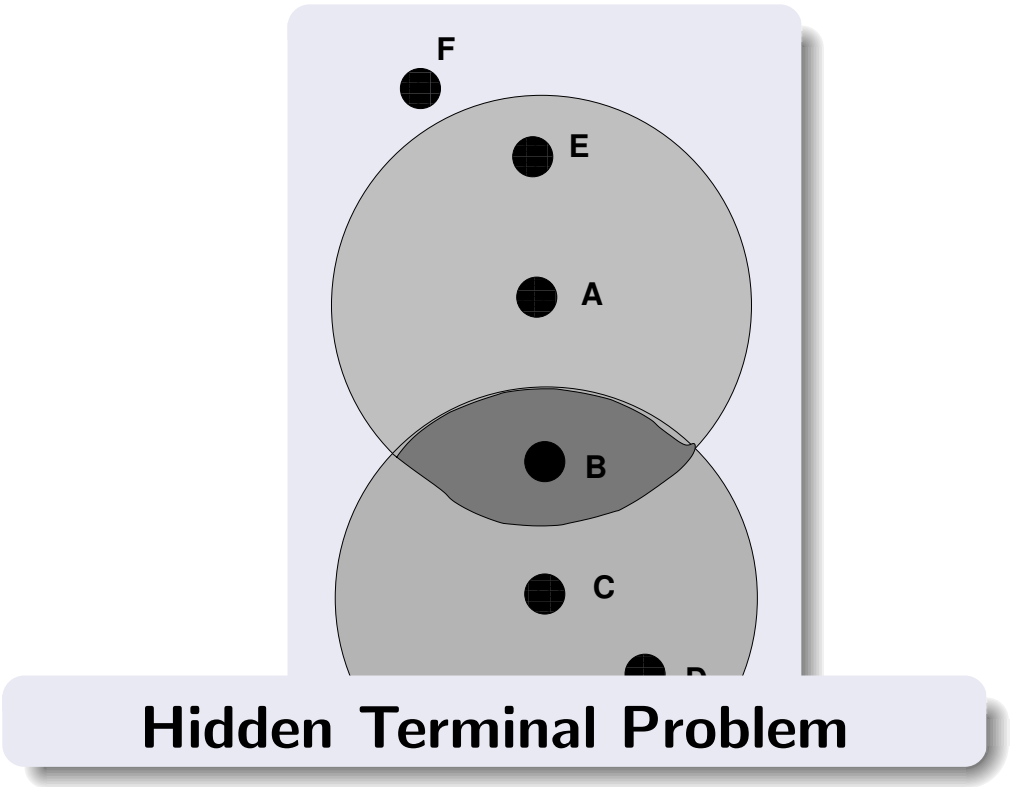

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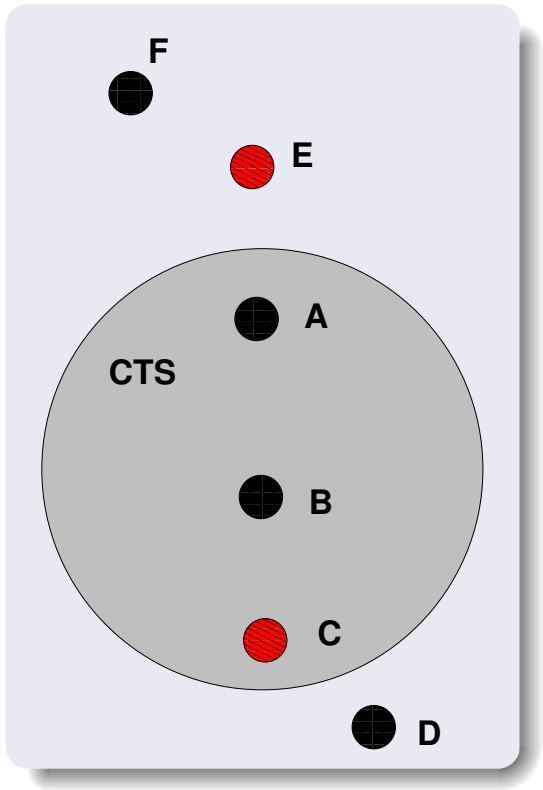

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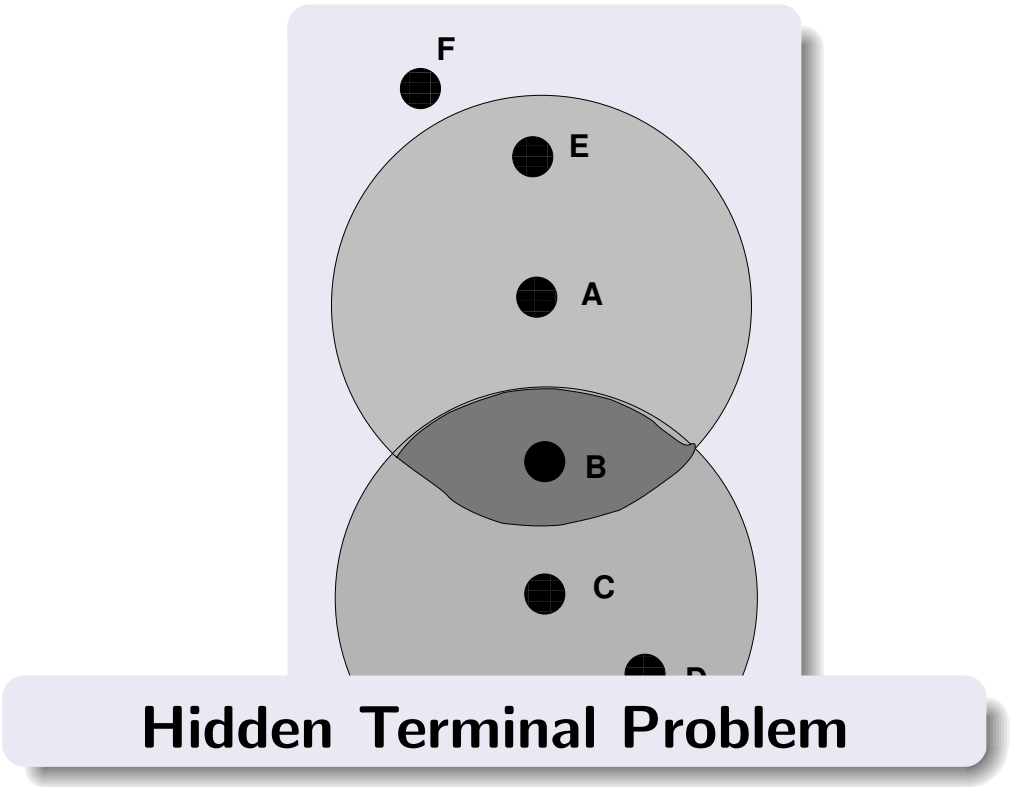

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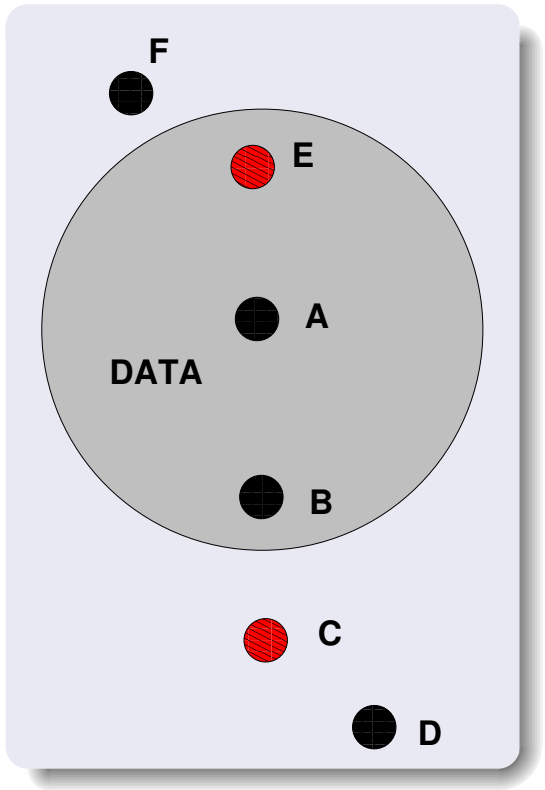

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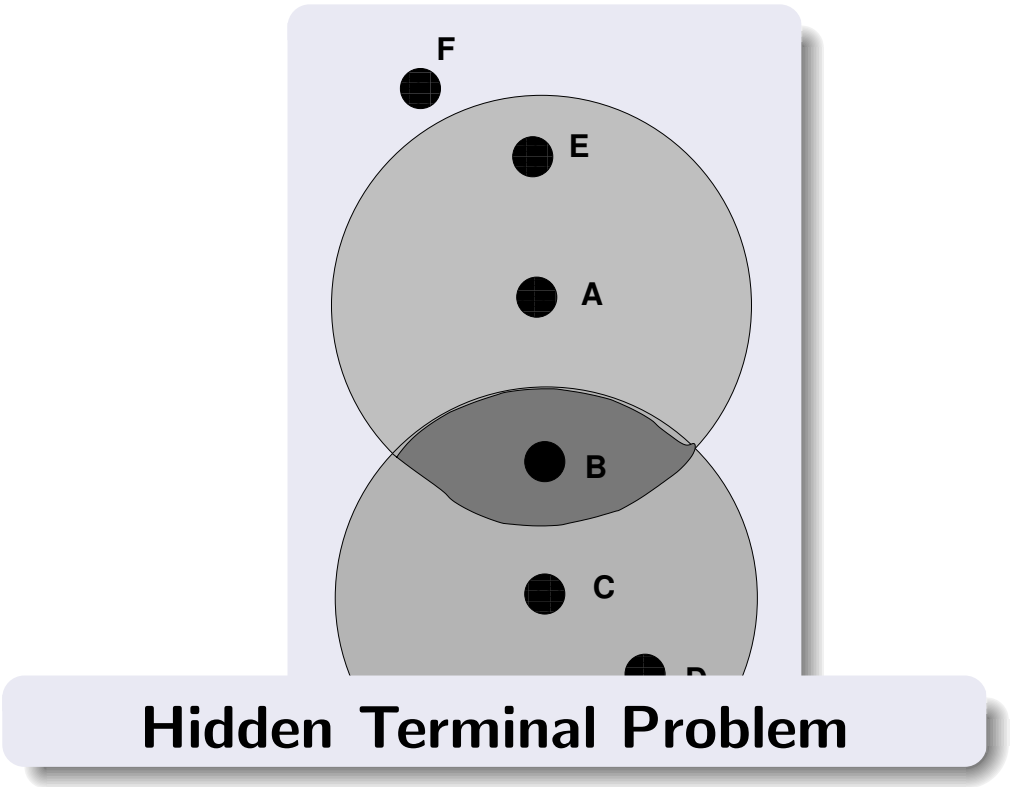

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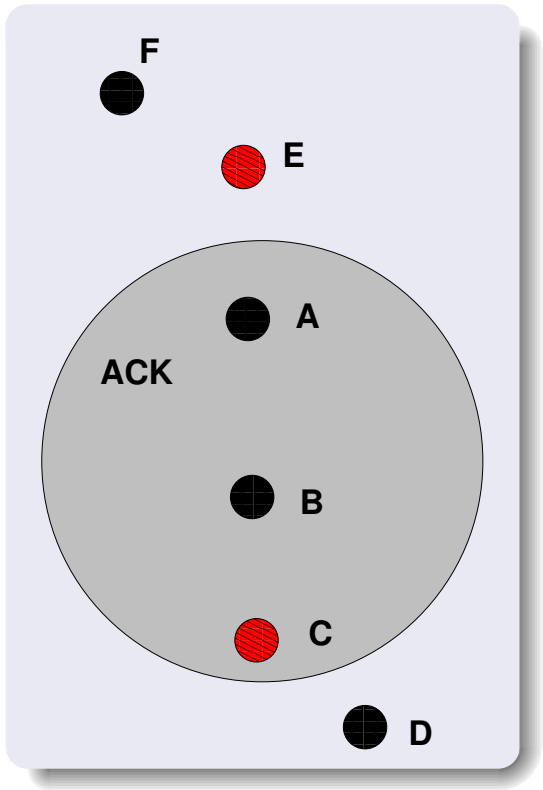

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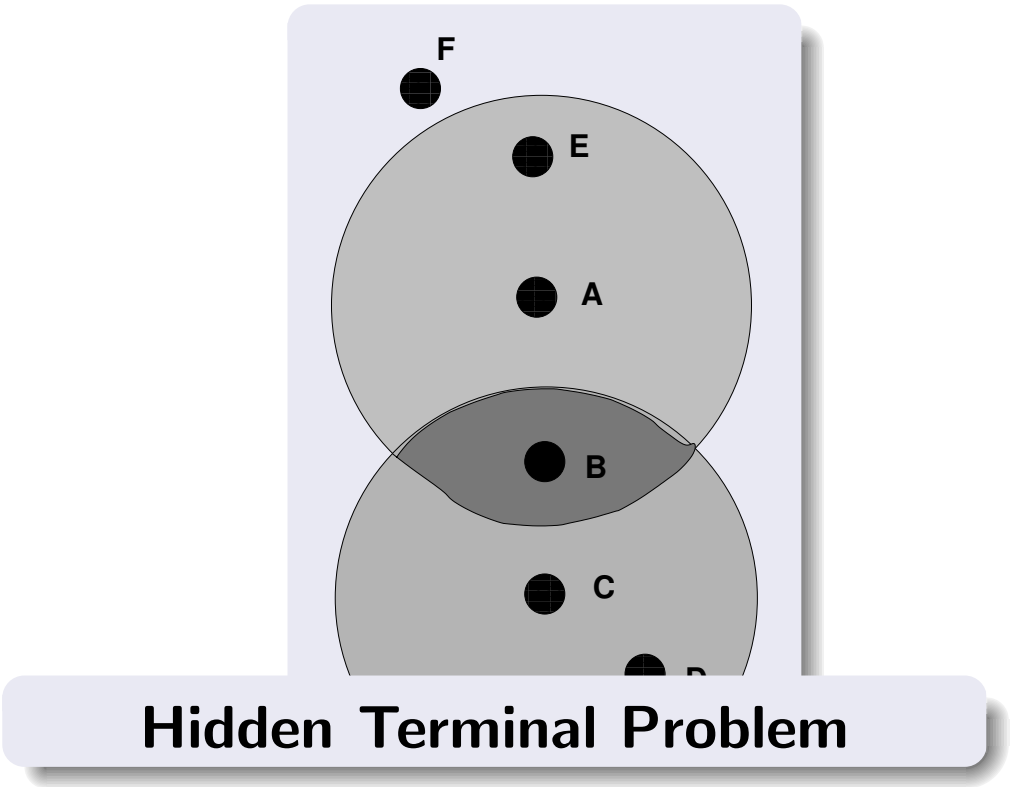

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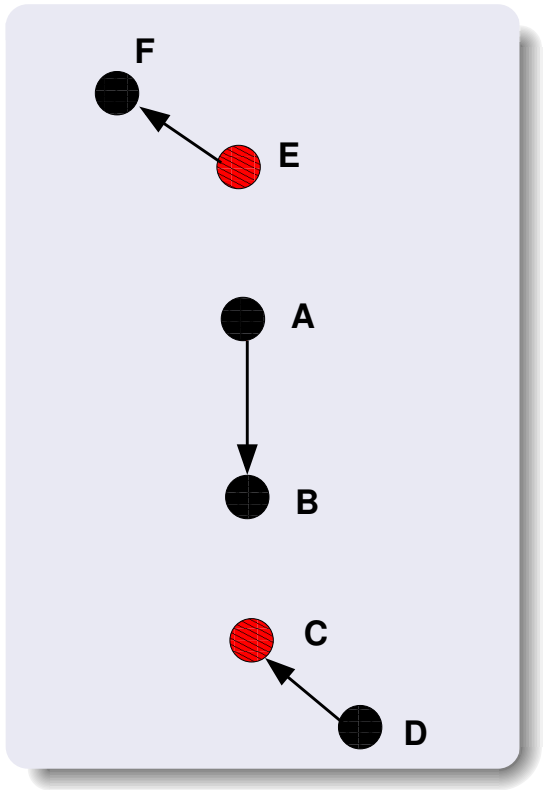

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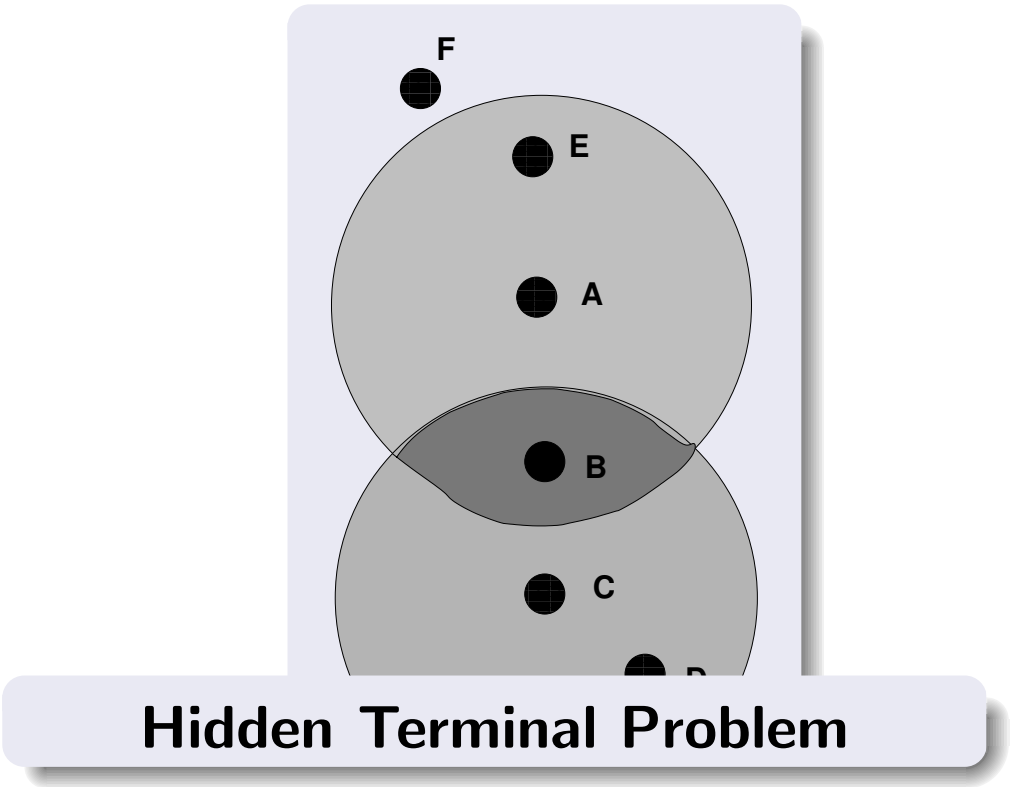

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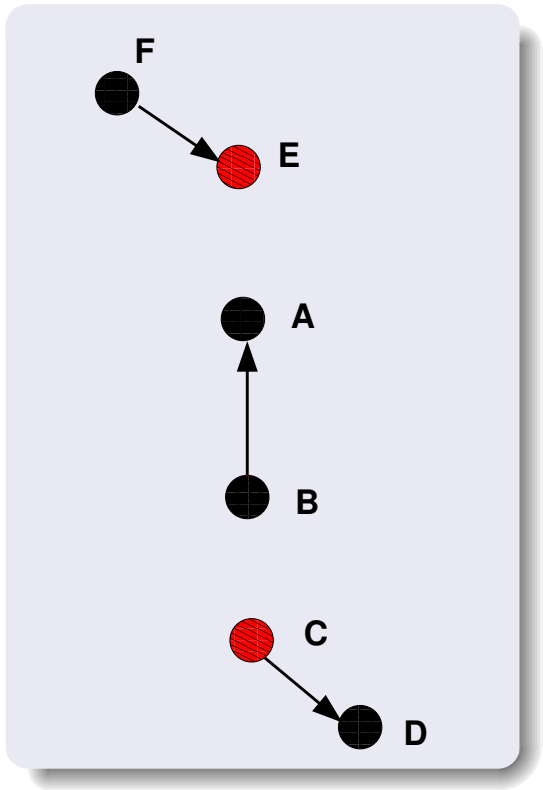

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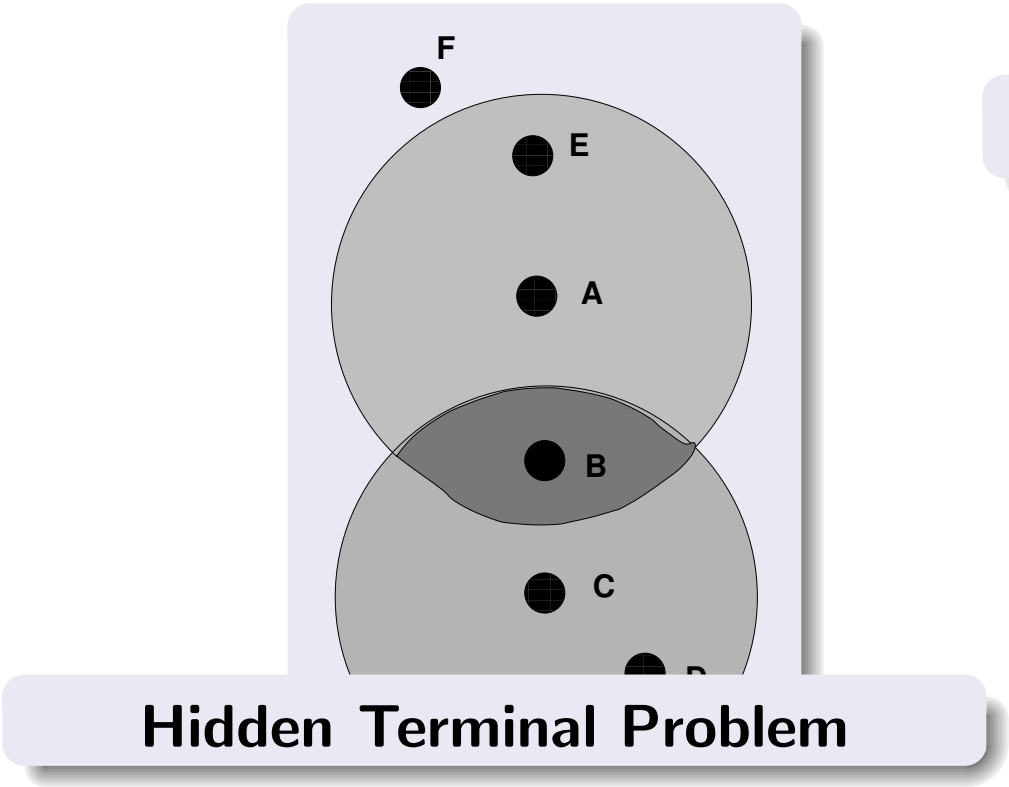

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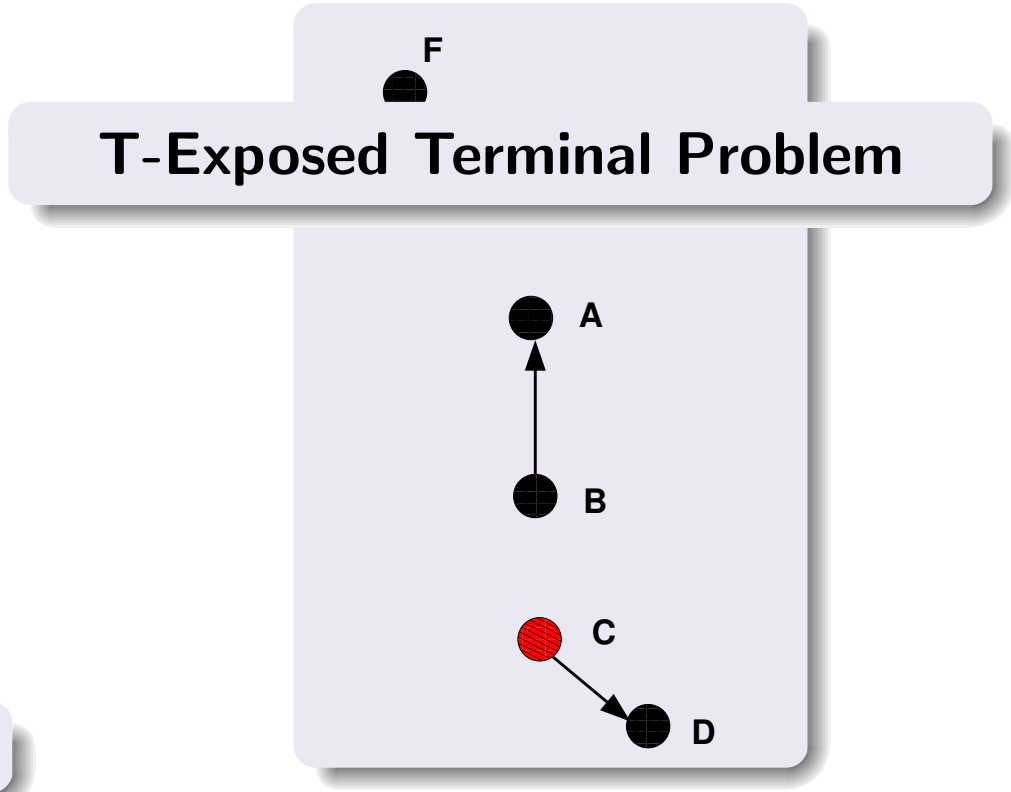

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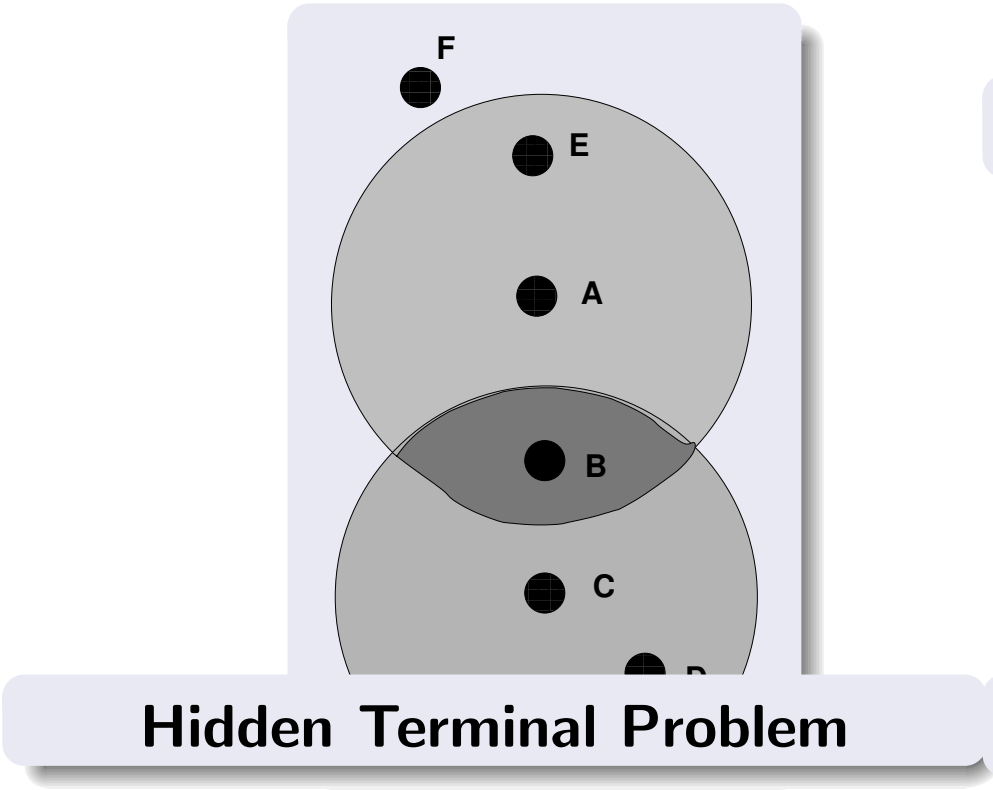
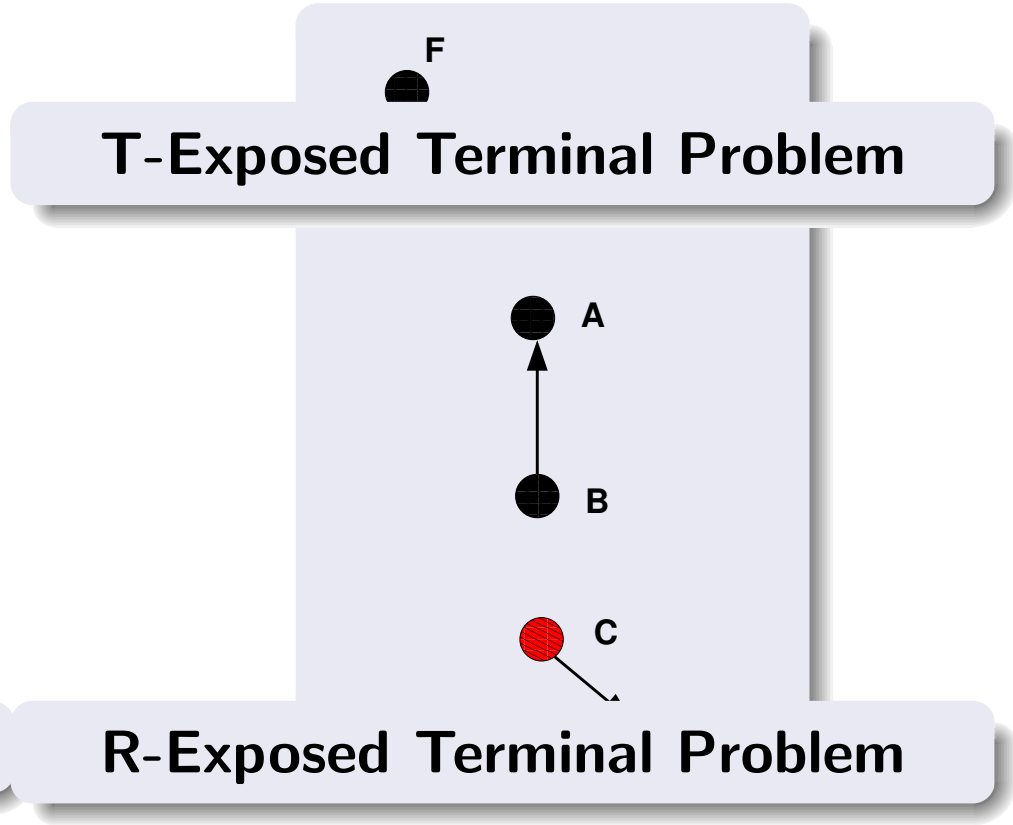




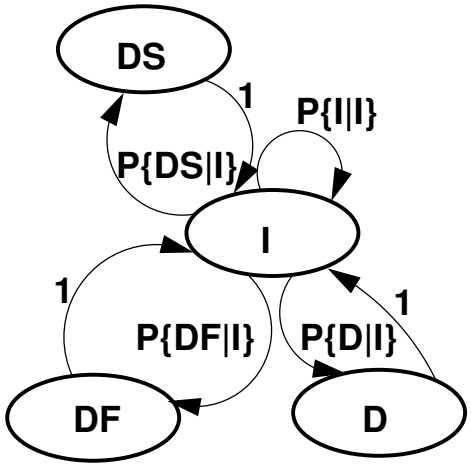
Hidden and Exposed Nodes

- Extensive studies have been carried out to mitigate with hidden and exposed nodes problem.
- For, IEEE 802.11b/g networks, solutions of hidden and exposed nodes require extra controlling overhead, which severe for a low to moderate loaded network.
- Four-way access may sometime impact in a negative performance[3]
- **Is the scenario similar for IEEE 802.11n high data rates?**

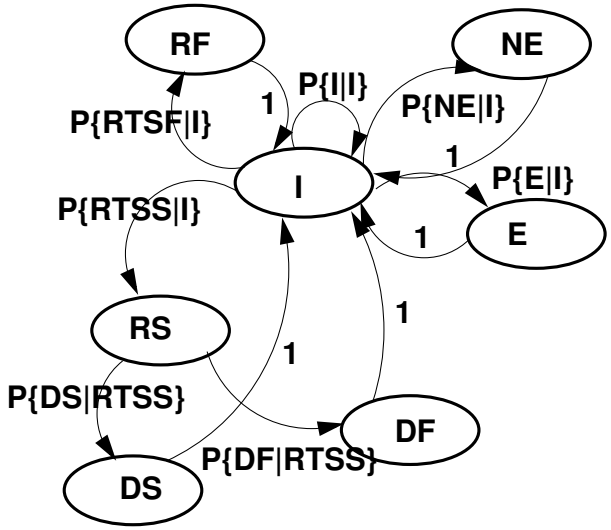
[3] R. Bruno, M. Conti, and E. Gregori. "IEEE 802.11 optimal performances: RTS/CTS mechanism vs. basic access." IEEE PIMRC, 2002.

IEEE 802.11n: Basic Access vs RTS/CTS Access

- Model basic access and RTS/CTS access, considering
  - High data rates
  - Frame aggregation (A-MPDU) : Channel is hold once access is successful
  - Block acknowledgements (BACK) : Loss in BACKs result in the loss in complete A-MPDU
  - A mesh network scenario: Contention is high



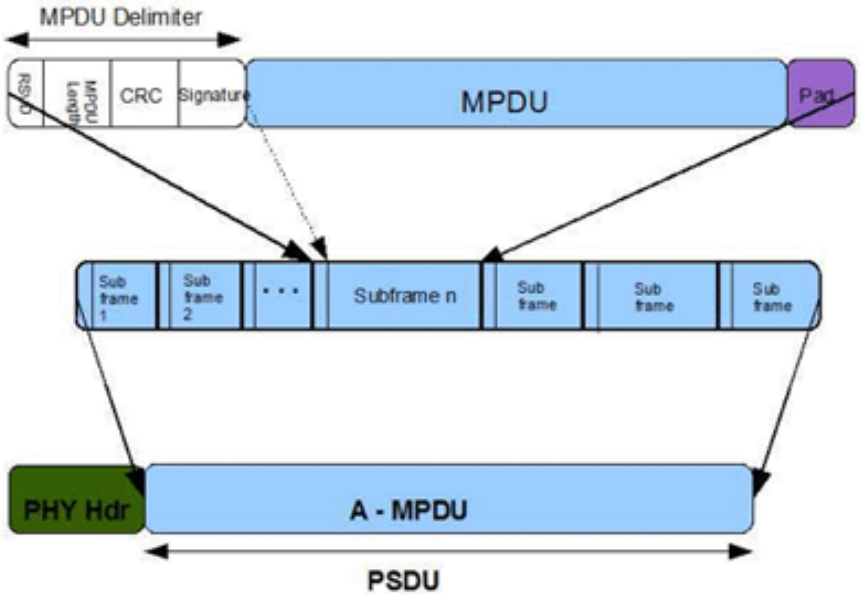
Basic Access



RTS/CTS Access

IEEE 802.11n: The Optimal Access

- Cost of expode nodes is very high: Channel is reserved for a large amount of time once access is successful.



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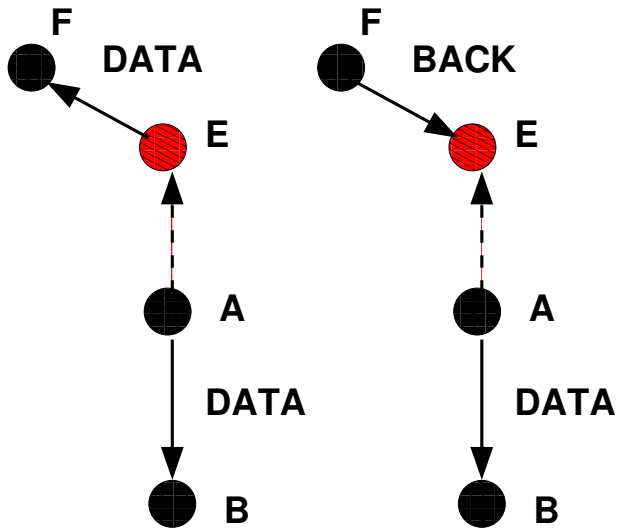
IEEE 802.11n: The Optimal Access

- However, access synchronization is crucial,
  - Possibility of data-BACK collision



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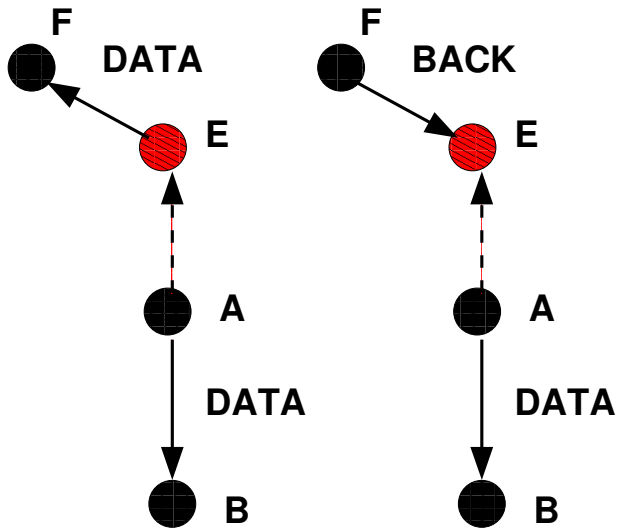
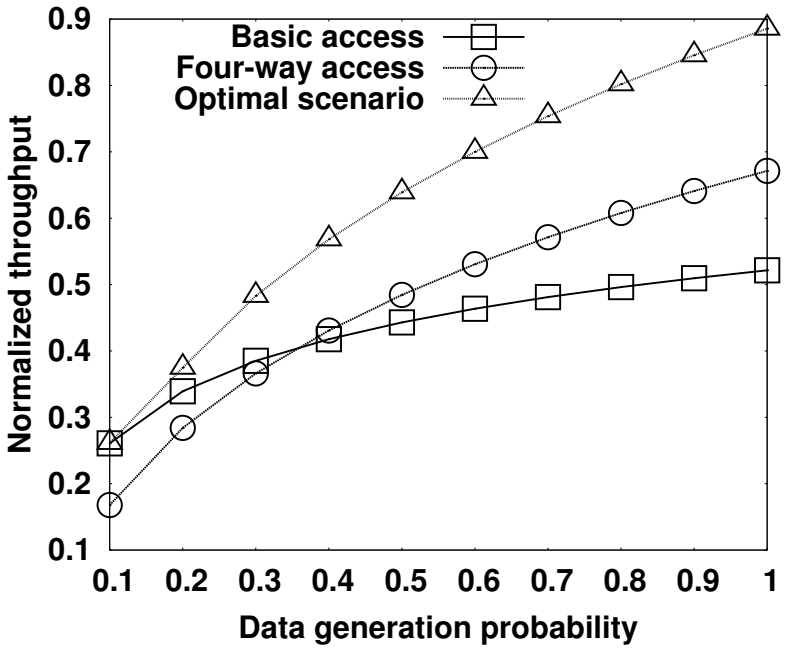
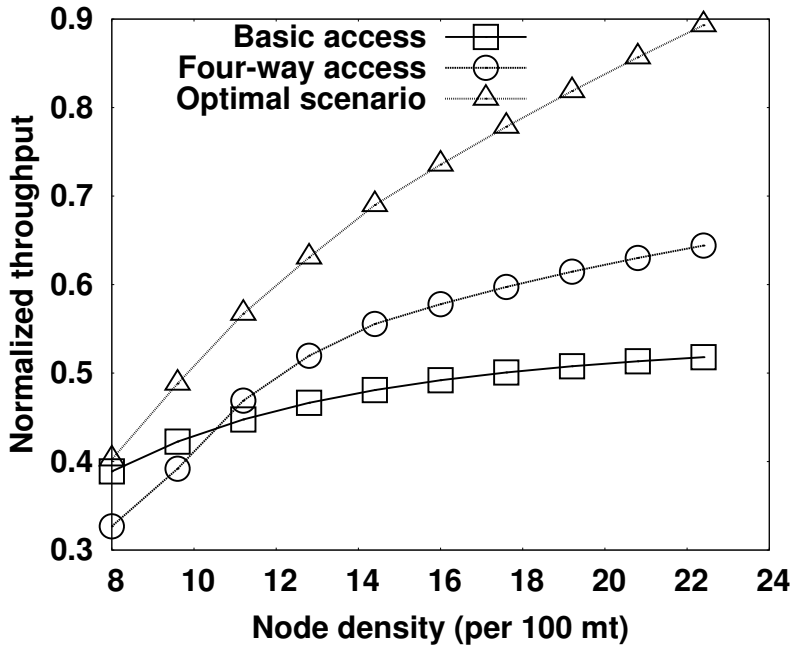


- **Optimal Access**:
  - No hidden nodes
  - No exposed nodes
  - DATA-BACK collisions are avoided

Outcomes from the Model: Numerical Results





Key Observations

- Can not avoid hidden nodes: effect of data loss is significant at high data rates, with moderate contention (basic access outperforms RTS/CTS only at very low contention).
- Exposed nodes result in severe underutilization.
- Keys for the good (near-optimal) performance:
  - Avoid hidden nodes (RTS/CTS access)
  - Allow transmissions for the exposed nodes (deviation from the original four-way access)
  - Avoid data-BACK collision whenever possible (opportunistic access)

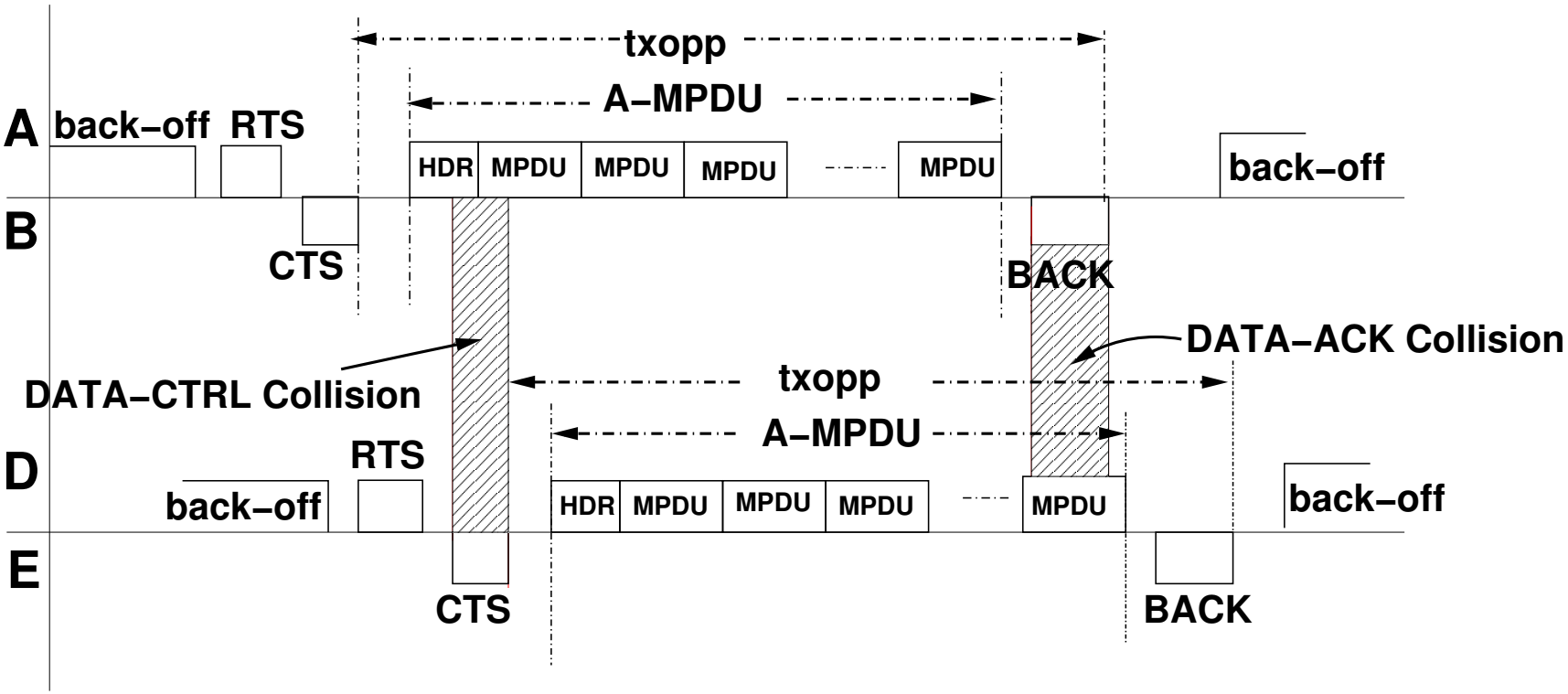
Opportunistic Four Way Access

- Allow transmission to the exposed nodes, but avoid hidden nodes
  - Maintain list of active nodes from which RTS and CTS are overheard (RTS_{act} and CTS_{act}).
  - $\mathcal{N}_S$: Set of one hop neighborhood for node S.
  - Node S wants to transmit to node R; Node S sends a RTS if $CTS_{act} = NULL$ and $\forall RTS_{act}.DST \notin \mathcal{N}_S$
    - $CTS_{act} = NULL$ implies no active receiver in the neighborhood
    - $RTS_{act}.DST$ also implies a receiver, so the second condition ensures no possible receiver in the neighborhood for the next few slots (there exists no such nodes in the neighborhood that has received a RTS, but yet to reply for a CTS)
    - Allows transmission for the T-Exposed nodes.

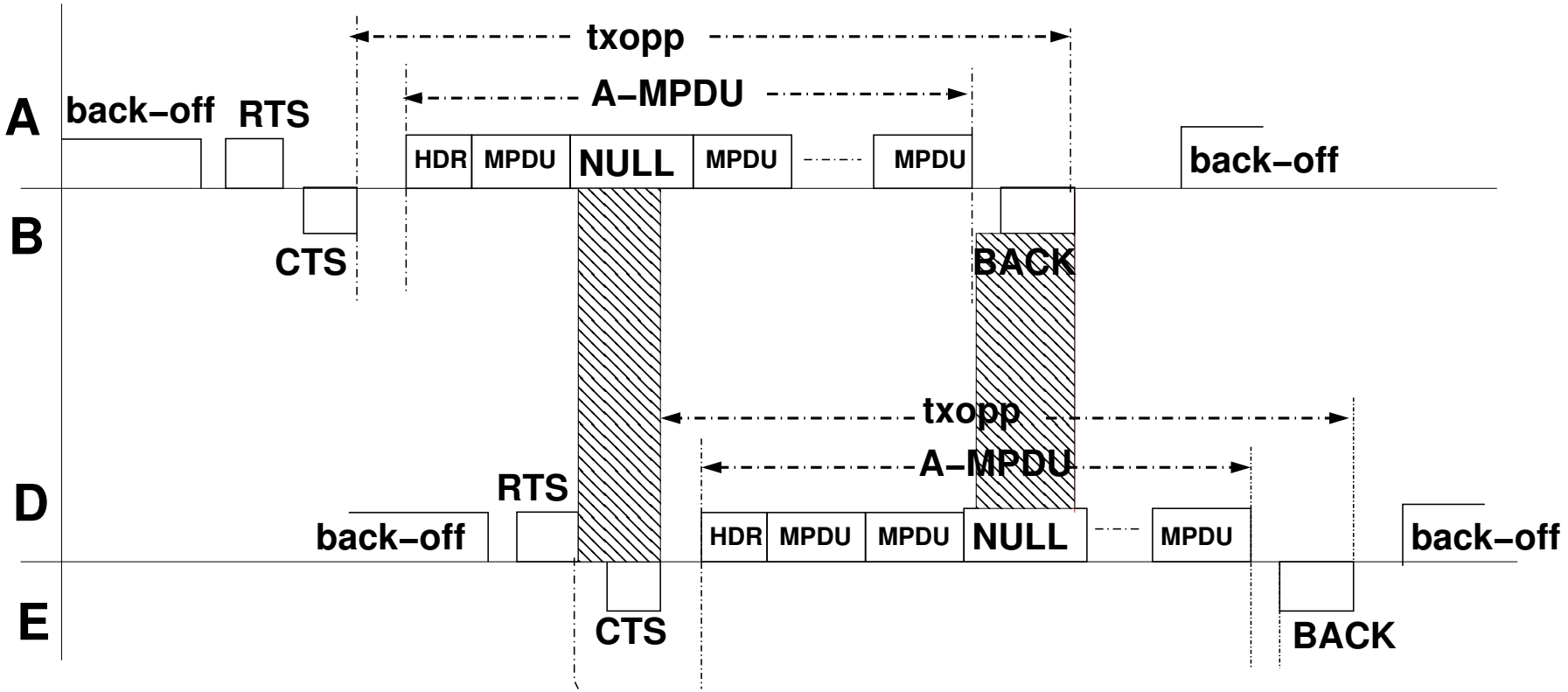
Opportunistic Four Way Access

- Node R receives an RTS from node S. It replies back with a CTS (wants to act as a receiver) only if,
  - $RTS_{act} = NULL$, ensures no active transmitter in the neighborhood
  - $\forall CTS_{act}.DST \notin \mathcal{N}_R$, ensures no CTS is overheard where transmitter is in the neighborhood (supports communication asymmetry)
  - Allows transmission for the R-Exposed nodes.

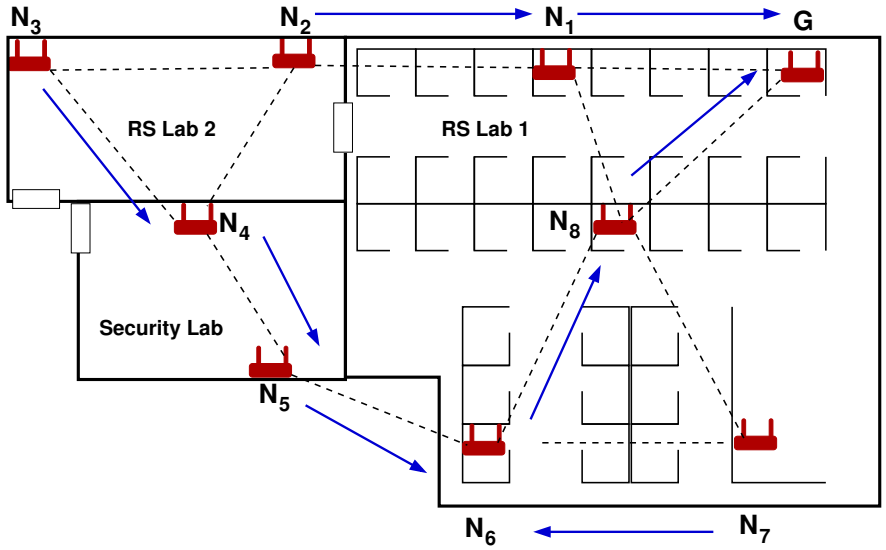
Opportunistic Access: Interference



Opportunistic Access: Interference Mitigation

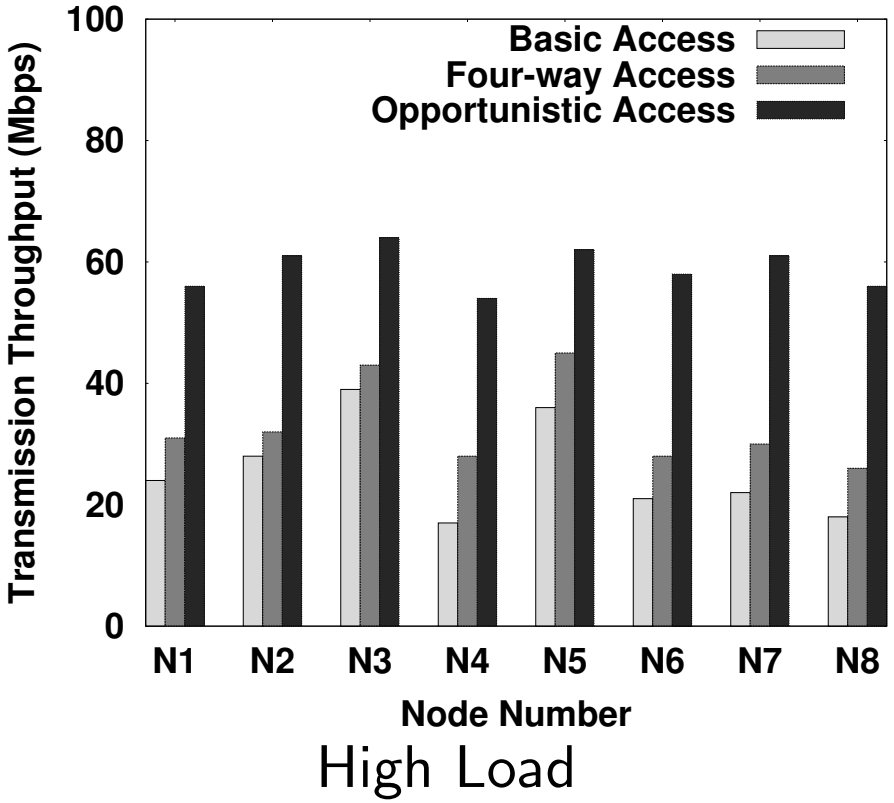


Testbed Evaluation

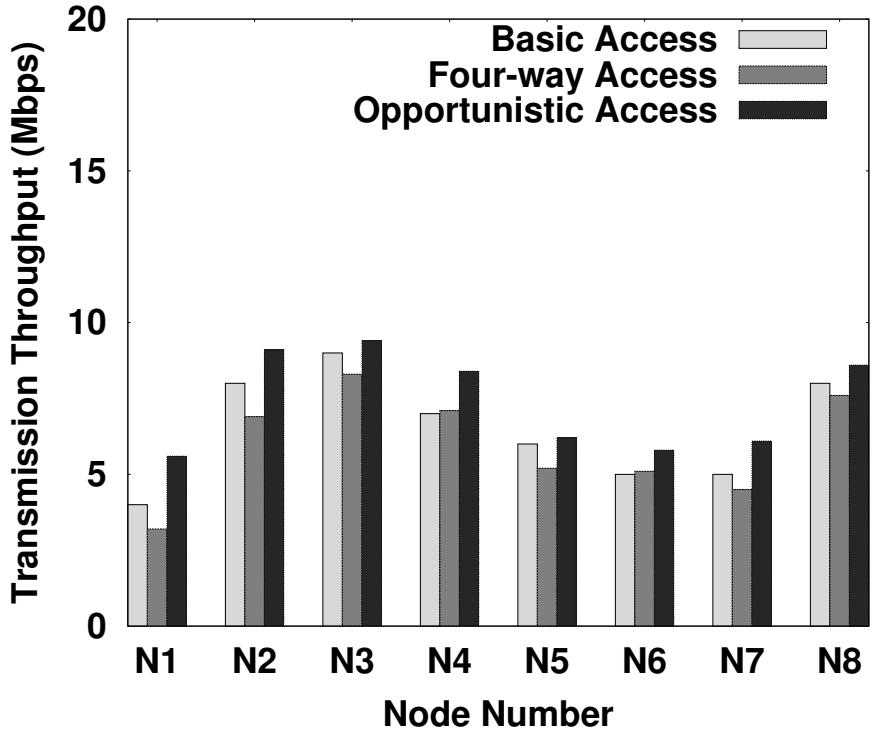


- Router: **RaLink RT-3352 RoC**: 2T2R MAC/BBP/PA/RF, 400MHz MIPS24KEc CPU, 64MB of SDRAM and 32MB of Flash
- IEEE 802.11n: 300 Mbps, channel bonding
- Open80211s: `http://www.open80211s.org`
- Linux Kernel 2.8.54
- TCP (FTP) and UDP (TFTP) using *iperf* (`http://iperf.sourceforge.net/`)
- Semi-indoor environment, Tx Power 16dBm, Rx Sensitivity 0 dBm (45-55 mt in indoor)

Performance: Throughput

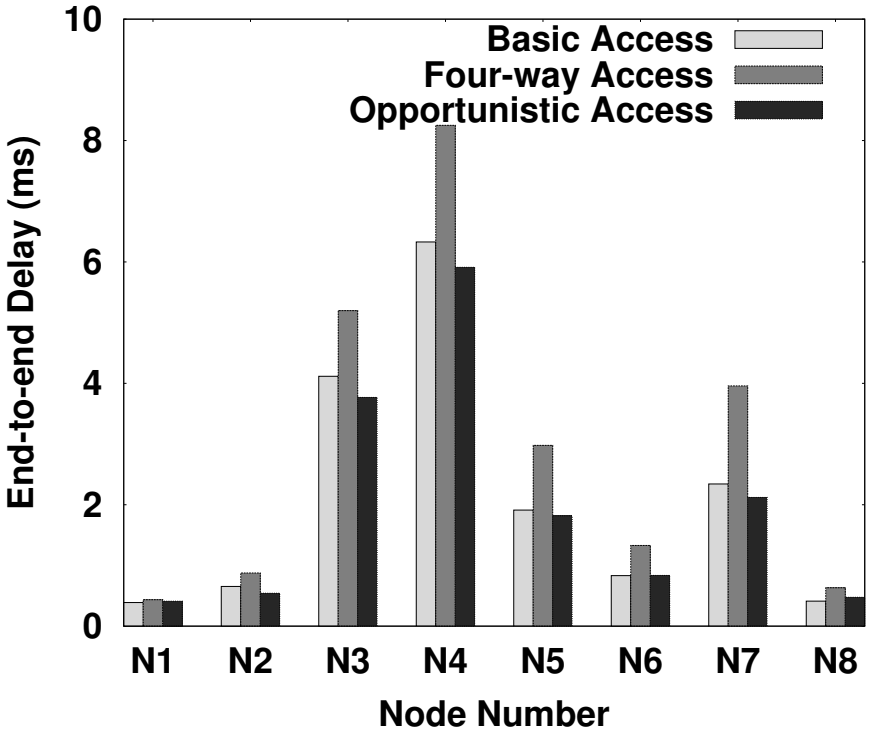


High Load



Low Load

Performance: Forwarding Delay



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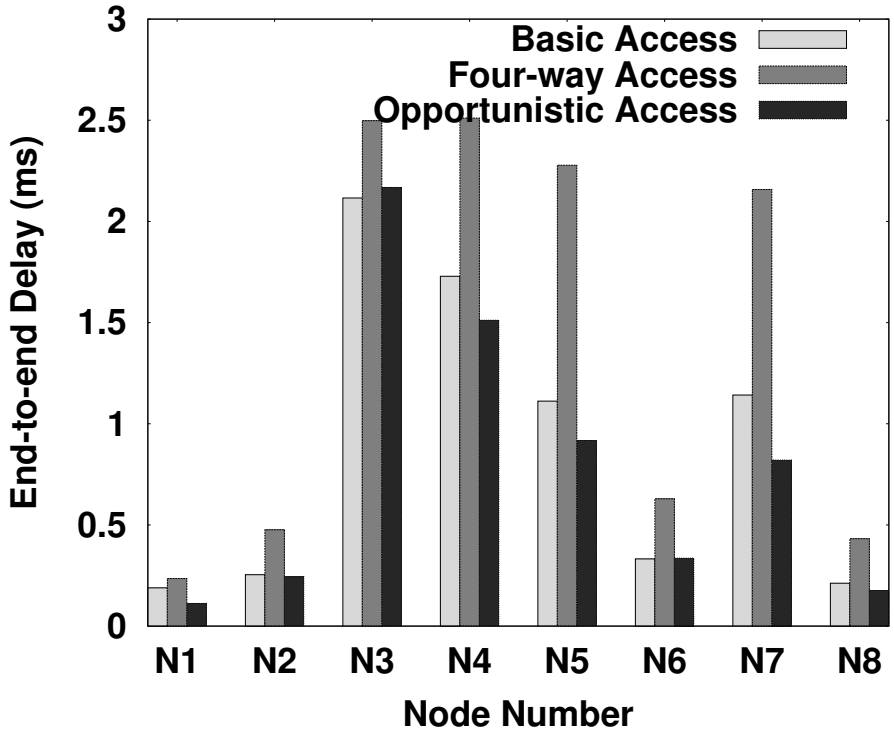
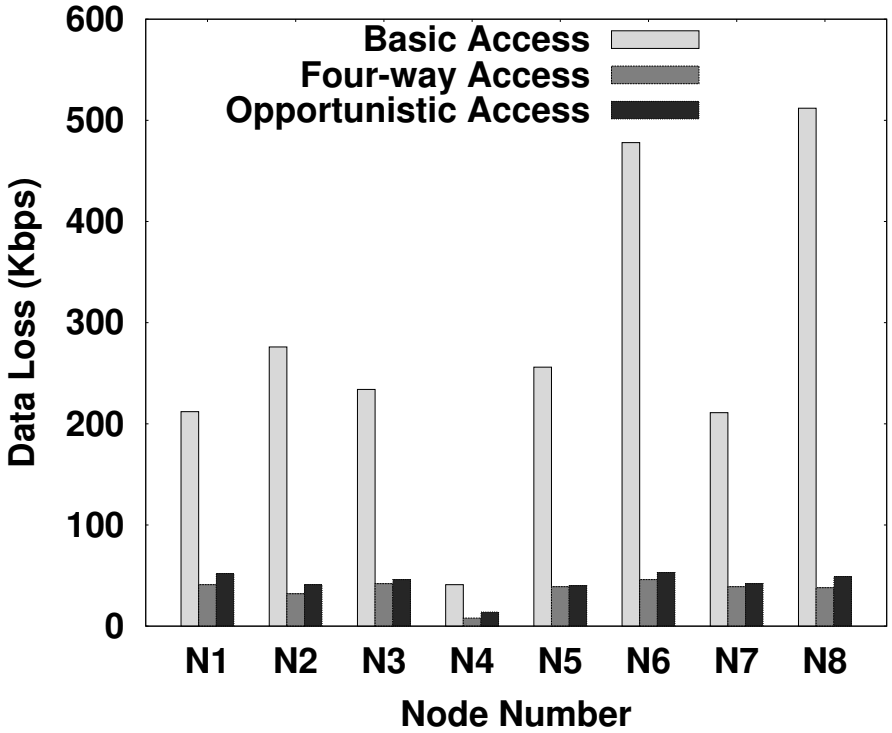
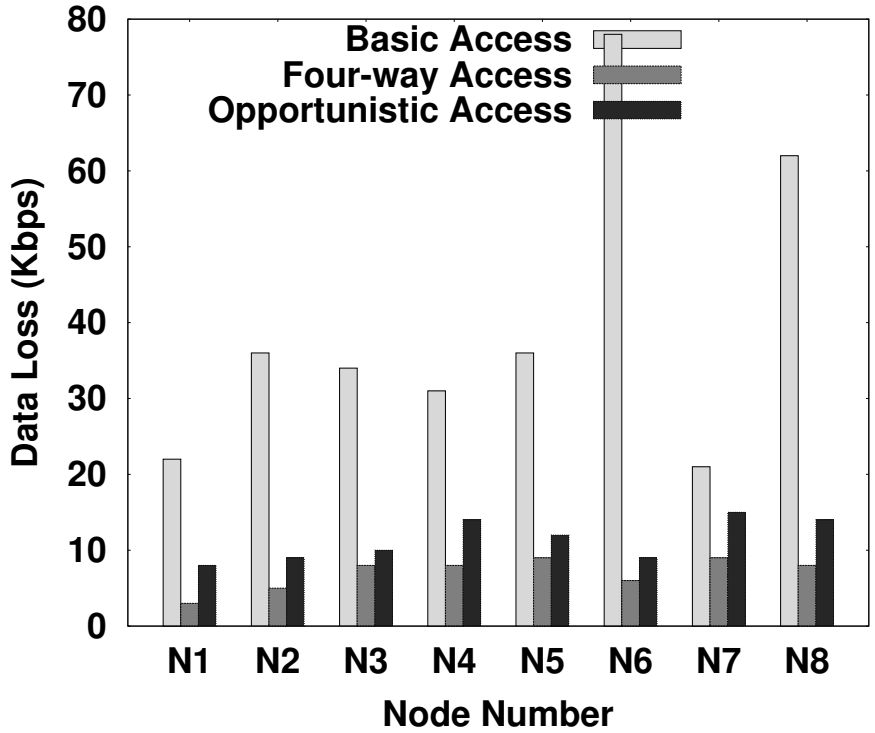


Low Load

Performance: Data Loss

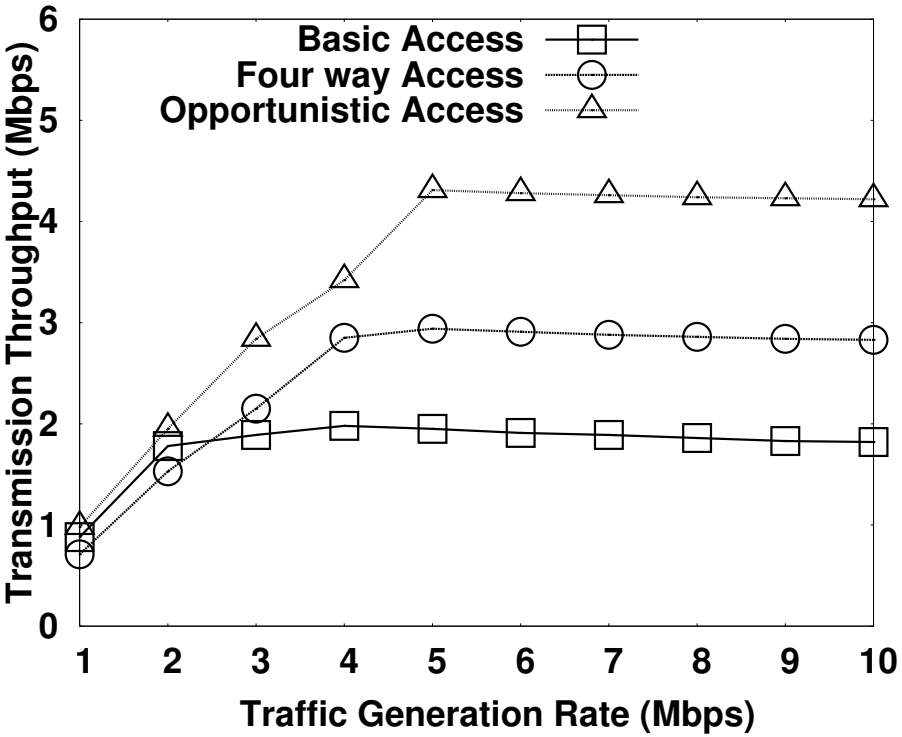


High Load



Low Load

General Performance Metrics



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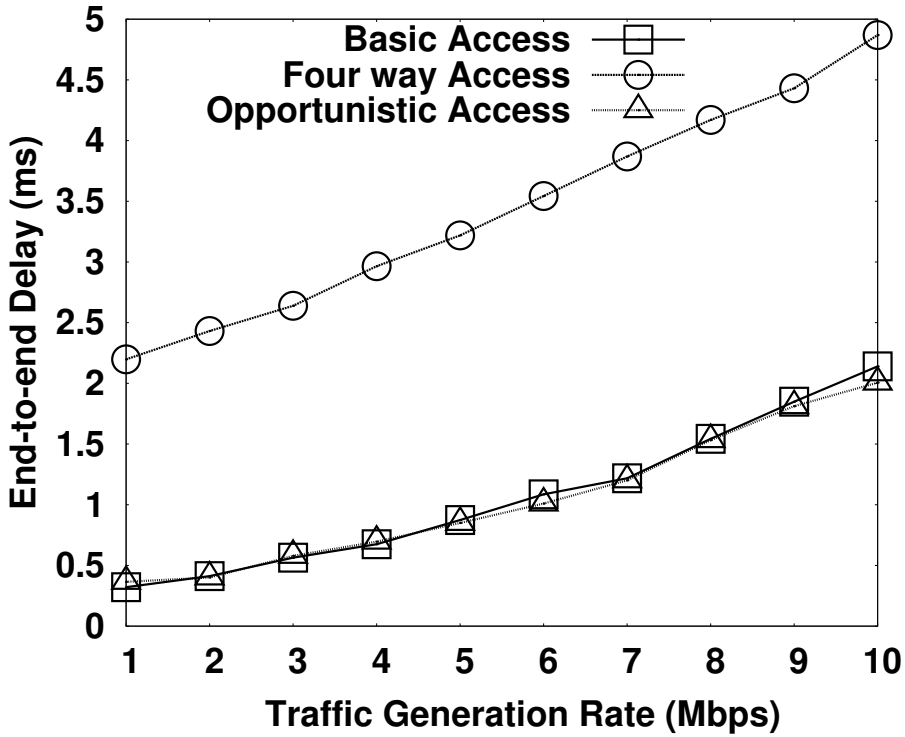

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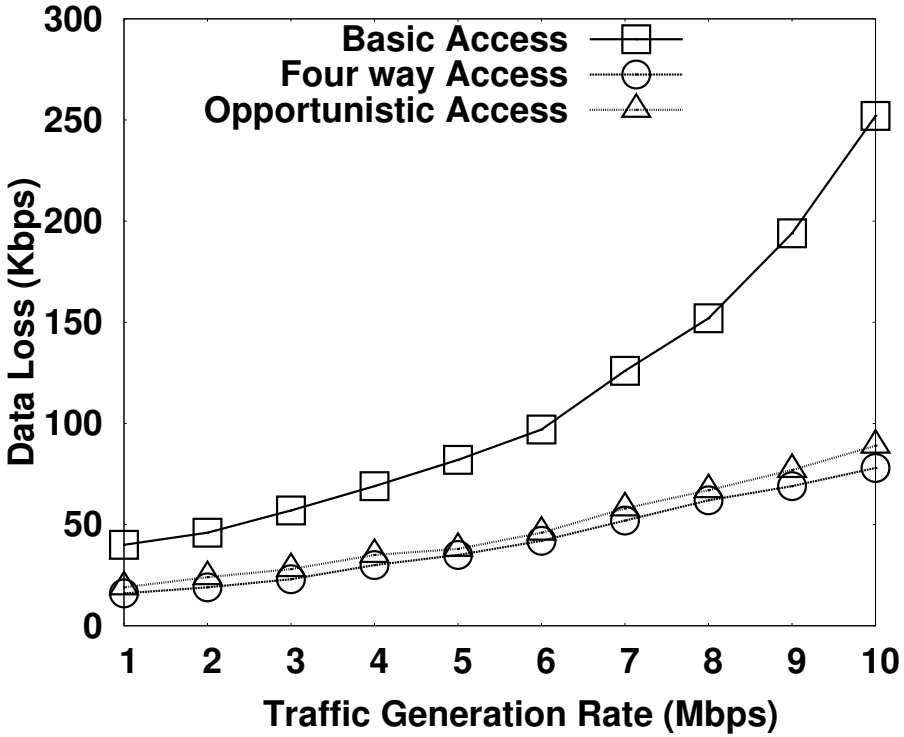
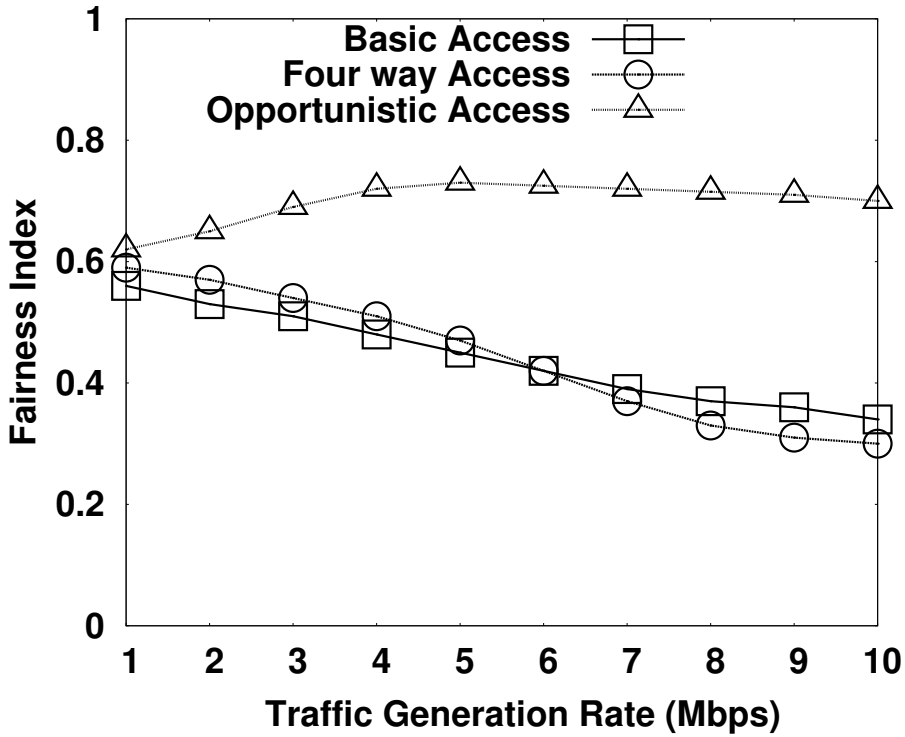


Data Loss



Fairness

Conclusion with Some Comments

- Explores the severity of hidden and exposed terminal problems over IEEE 802.11n
- Proposed an opportunistic solution to improve MAC performance over IEEE 802.11n
  - Distributed as well as localized
  - Less control overhead
  - Improved spatial reuse
- This paper has considered IEEE 802.11n with A-MPDU aggregation. However the compatibility of this solution with the existing basic and four way access is further required to be investigated.
  - How does the opportunistic solution perform in mix network of basic access, four-way access and opportunistic access?
  - How does the proposed solution scale with number of nodes in the network?

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Thank You