Wireless Network Security
Spring 2016

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Class #15 – Wireless Transport Security

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- Fun issues at the wireless transport layer

- Transport-oriented attacks

Transport Layer

- Transport layer is responsible for managing end-to-end content delivery
  - Connection-oriented communication
  - Reliability
  - Flow control
  - Congestion avoidance
  - Multiplexing
  - Ordered delivery

Wireless Multihop Transport

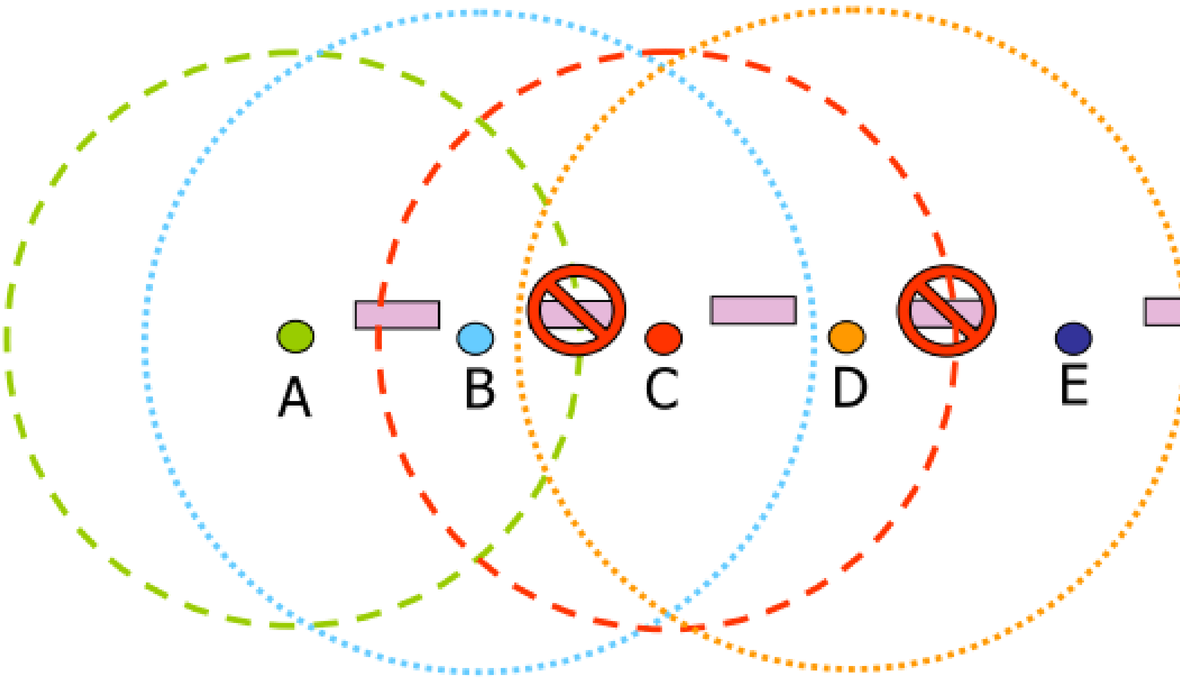
- Transport performance is affected by all protocols living below it
  - Physical layer
    - Errors can be misinterpreted by transport mechanisms: one of the big reasons TCP has difficulties in wireless
  - MAC
    - Transport flows suffer from inter- and intra-flow contention
  - Network layer
    - Transport sessions live only as long as routing paths; path maintenance → session maintenance
    - Mobility: path disconnection/loss causes different behaviors in different routing protocols, all of which affect transport

Phy → Transport Impact

- TCP interprets errors and tries to mitigate their effects using congestion control
  - But, it usually can't distinguish congestion loss from transmission errors
  - Congestion control may be invoked when not needed
  - TCP + transmission errors → reduced throughput

MAC → Transport Impact

- More hops/path means more medium usage
  - Increased competition for medium, even among nodes in the same routing path
  - Higher interference and hidden/exposed terminals



Mobility → Transport Impact

- Node mobility leads to route changes
  - Route can fail, data lost on old route, new route formed, TCP timeout starts data on new path

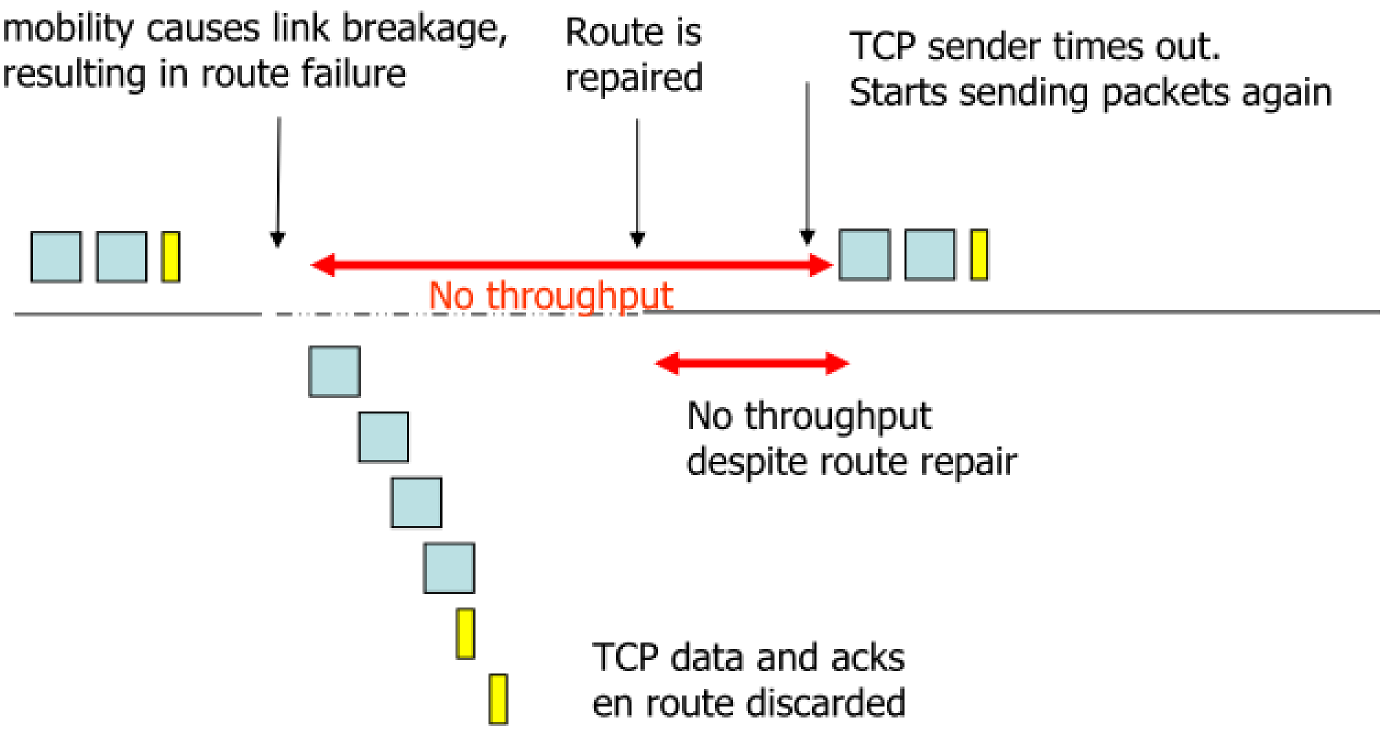


Image source: [Vaidya, Infocom 2004]

Mobility → Transport Impact

- Node mobility leads to route changes
  - Route can fail, shorter route formed

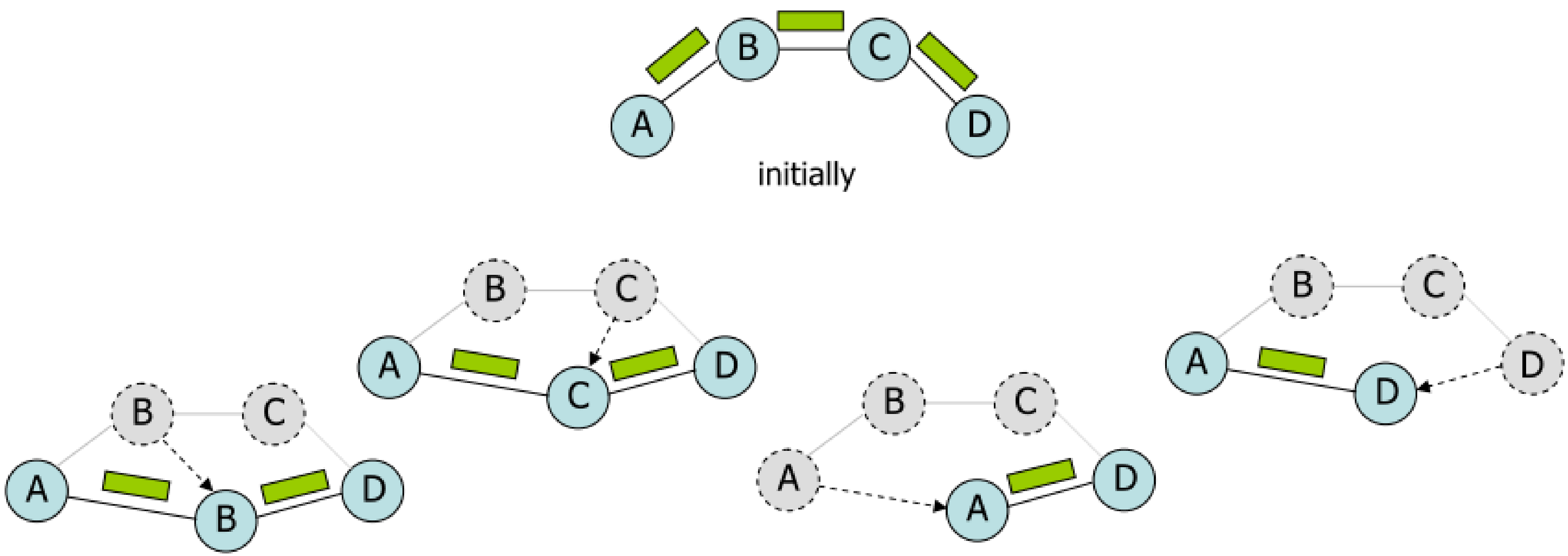


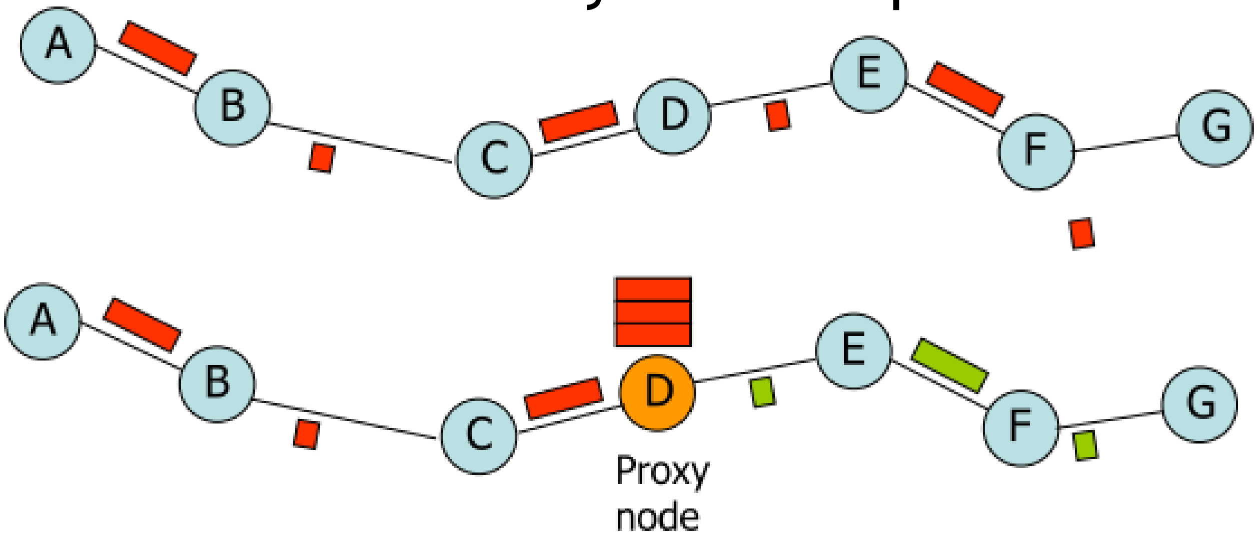
Image source: [Karaliopoulos, ETH lecture 2007]

Routing → Transport Impact

- Route caching interferes with TCP (e.g., in DSR)
  - Multiple routes stored to reduce discovery overhead
  - At network layer, source scans for a live route
    - Older routes may have been broken due to mobility, etc.
    - Successive TCP timeouts, lack of data traffic during scan
  - Instead:
    - Deactivate route caching
    - Explicit link failure notification (TCP-ELFN)
    - Explicit congestion notification or ICMP unreachable messages (ATCP)

Split TCP

- In mixed wired/wireless:
  - TCP runs only at the end-points and at a proxy at the wired/wireless border
  - Proxy accelerates traffic through wired domain
- In wireless multihop:
  - Proxies can be similarly used to split into short paths



Split TCP Pros/Cons

- Pros:
  - Improves multi-hop TCP opportunity using shorter loops and faster evolution
  - Retransmissions follow shorter paths, saving energy and reducing interference
- Cons:
  - Breaks E2E, so no longer compatible with end-to-end security such as IPSec
  - Increased buffering at proxies, required greater intelligence at intermediate nodes
  - Route changes/breaks require proxy changes

Misbehavior

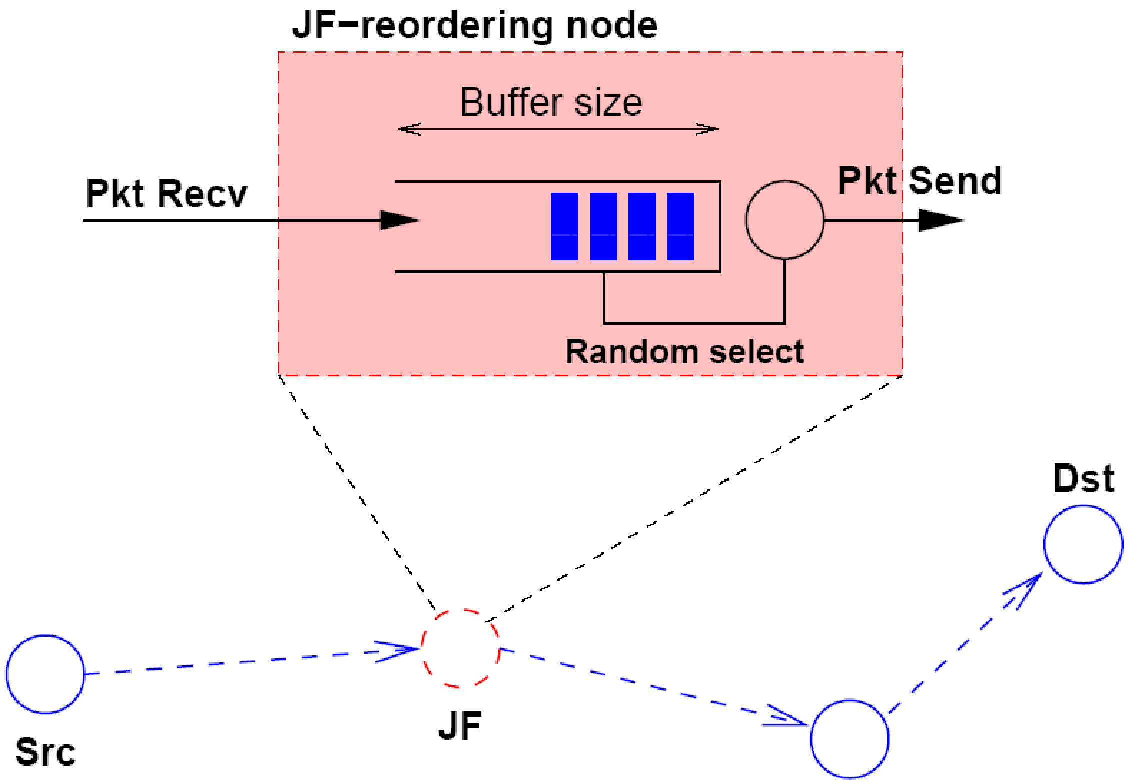
JellyFish Attacks

[Aad, Hubaux, and Knightly; MobiCom 2004]

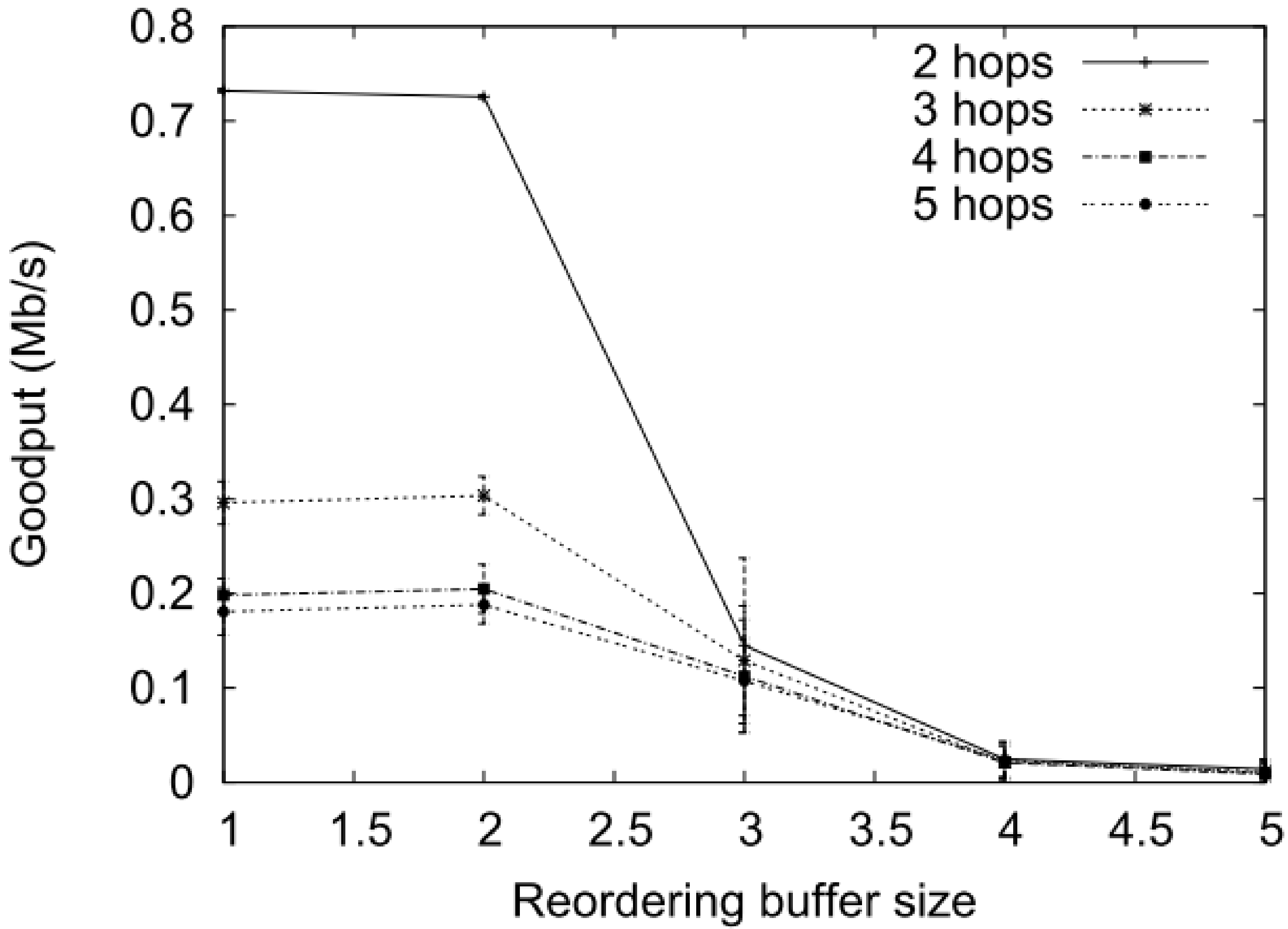
- JellyFish (JF) attacks target congestion control used in many TCP and UDP variants
  - JF attacks comply with all control and data plane protocol requirements except for targeted malicious actions including:
    - Re-ordering packets
    - Periodically dropping packets
    - Increasing delay variance

JF Re-ordering

- TCP uses cumulative ACKs for efficiency and rely on duplicate ACKs to detect loss or out-of-order reception
  - All TCP variants assume that packet re-ordering is a relatively rare and short-lived event
- JF Re-ordering attack
  - Deliver all packets but using a re-ordering queue instead of a FIFO queue

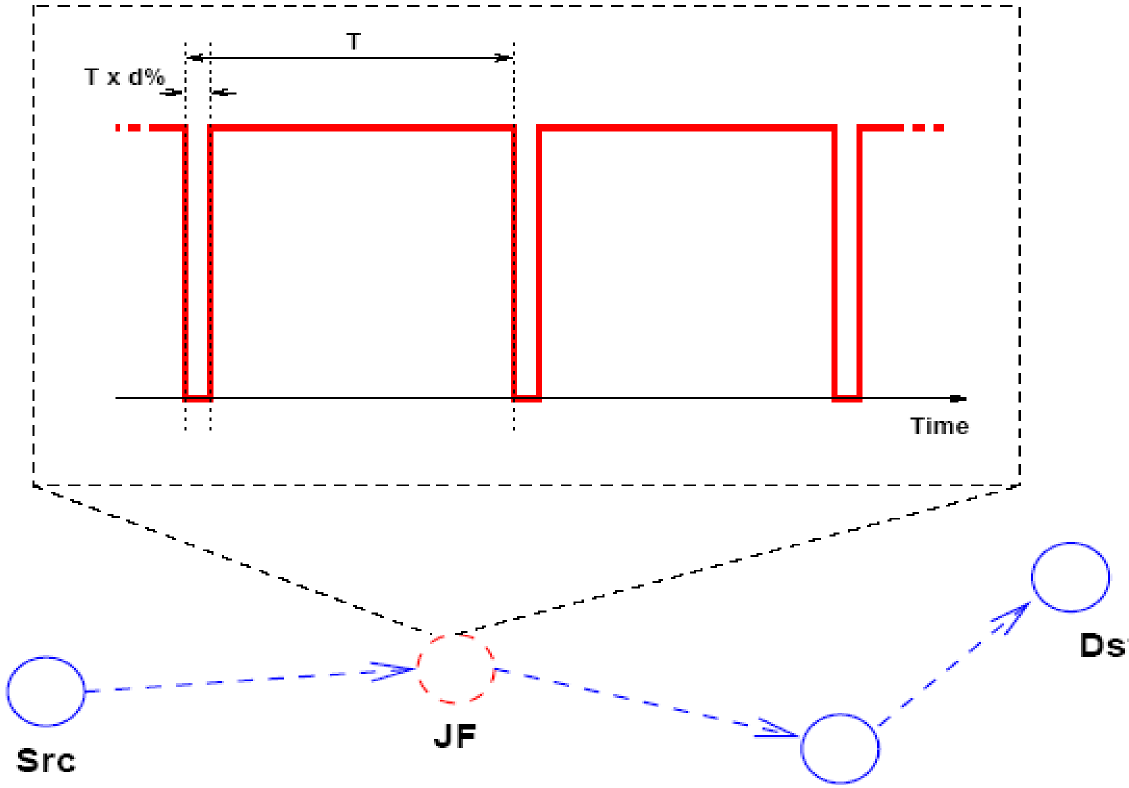


Impact of JF Re-ordering

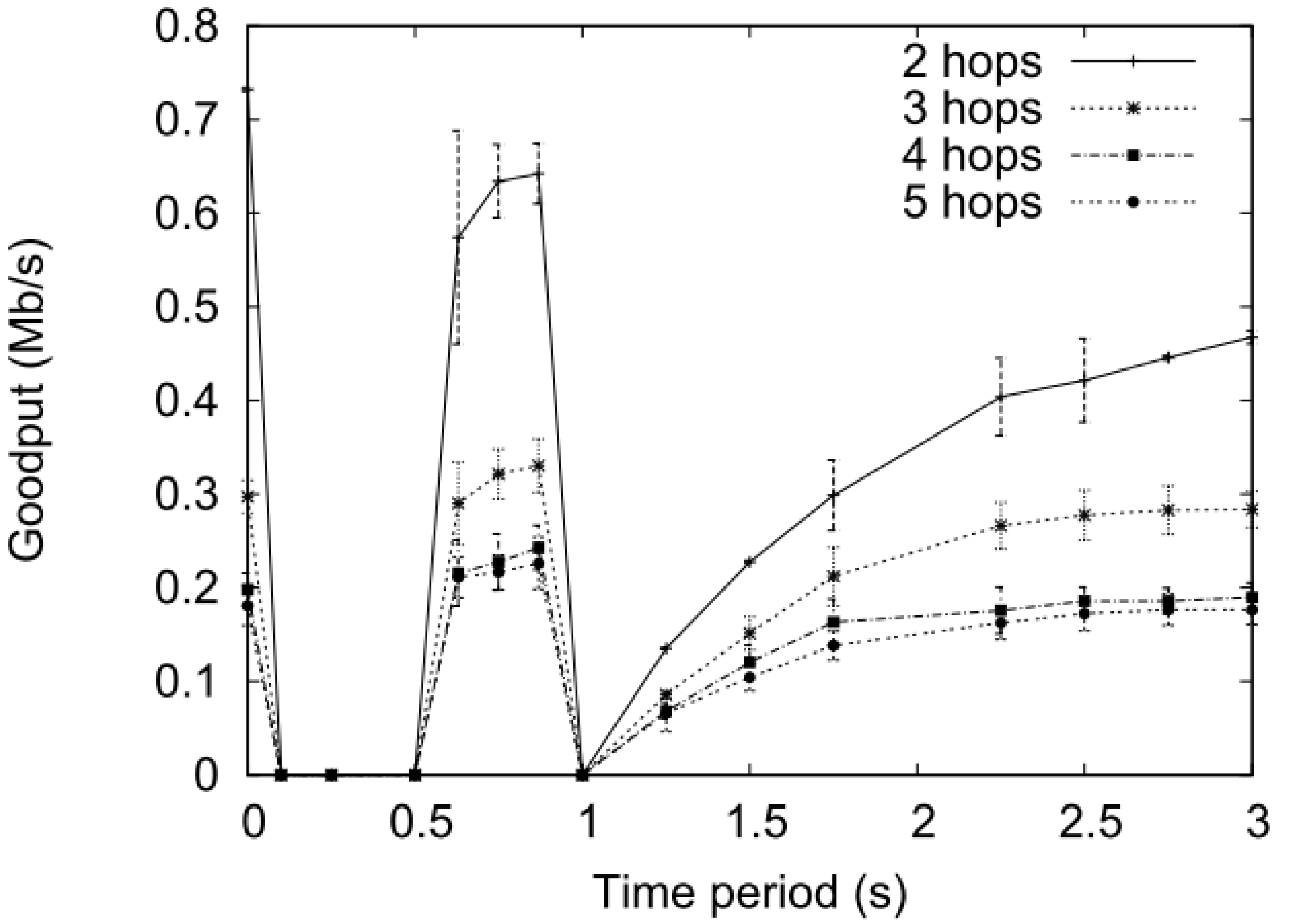


JF Periodic Dropping

- If packet loss occurs periodically near the retransmission time out scale (~1s to address severe congestion), then E2E throughput is nearly zero
- JF periodic dropping attack
  - Drop packets for a very short duration with period near the retransmission time out

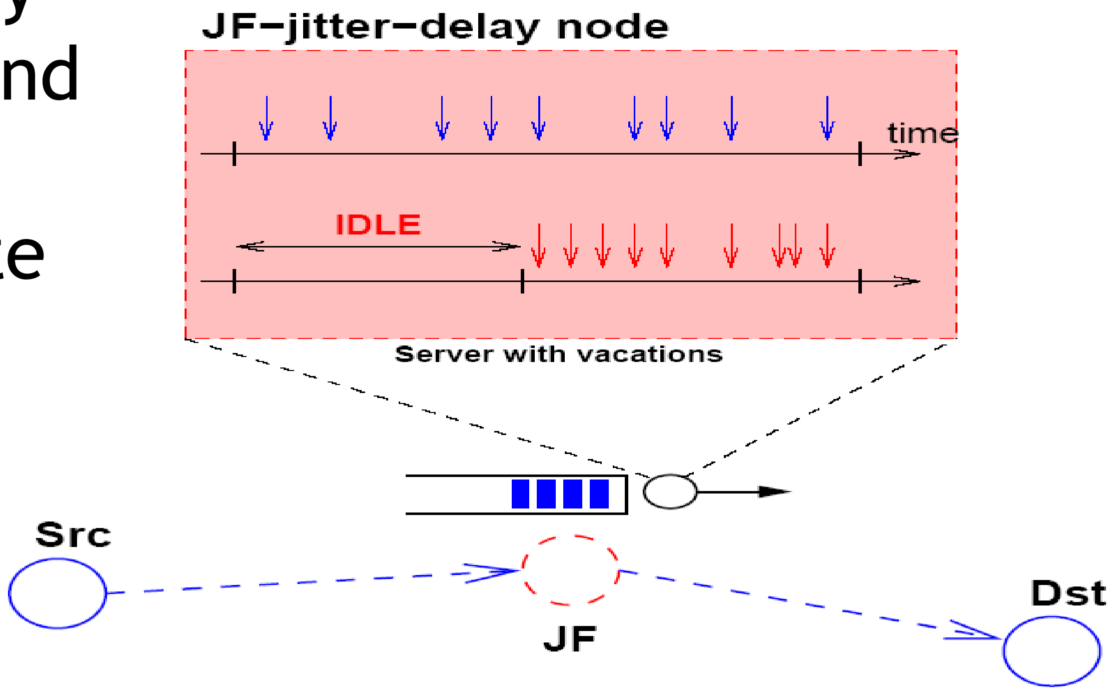


Impact of JF Per. Dropping

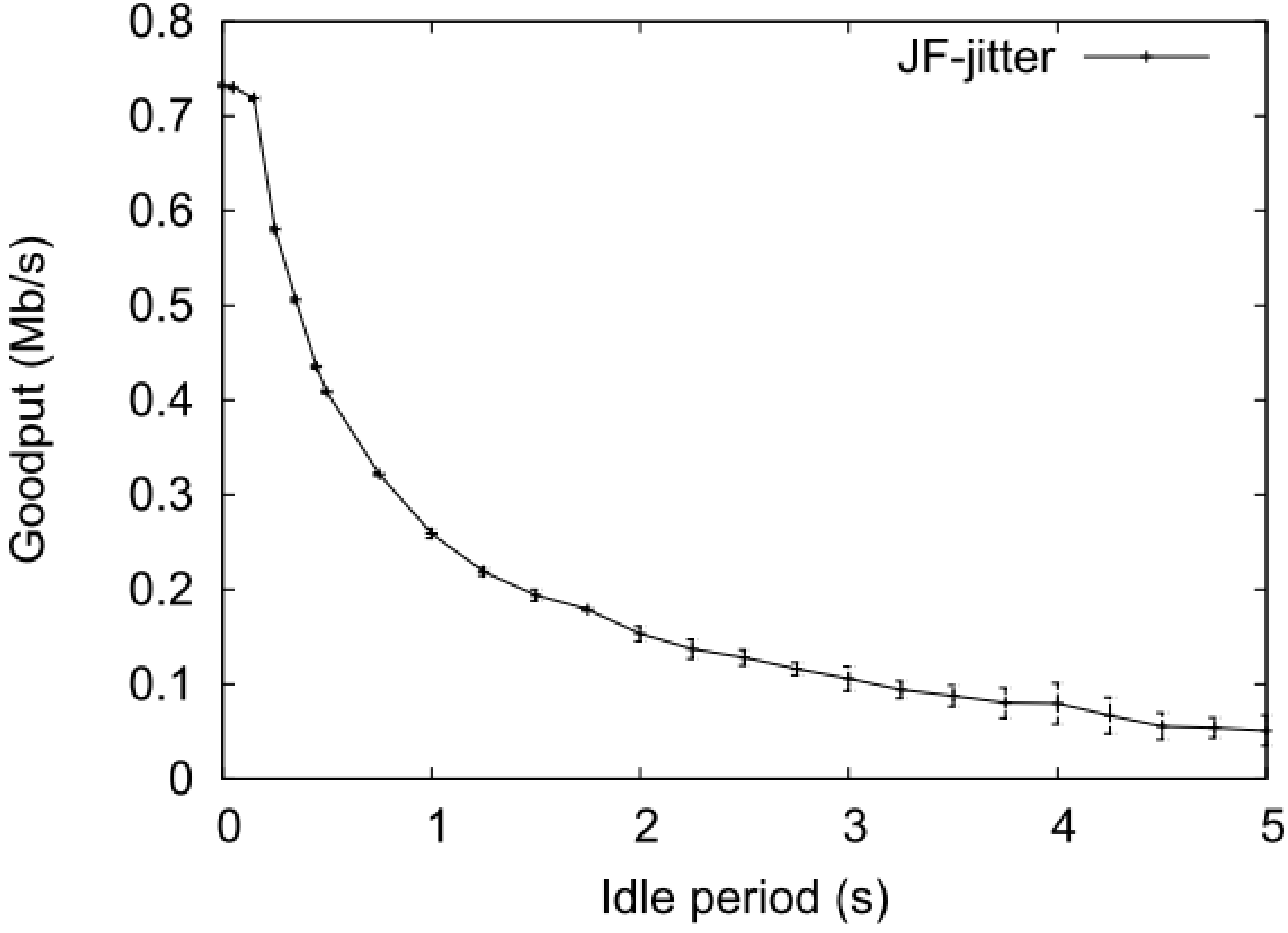


JF Delay Variance

- Round-trip times vary due to congestion, and this variance is measured to estimate important protocol parameters
- JF delay variance attack
  - Inject random delay in forwarding each packet, maintaining order, but increasing delay variance



Impact of JF Delay Variance



Detection of JF Attacks

- Detection relies on ability to monitor forwarding behavior
  - Using passive ACK or “overhearing” (e.g., Watchdog)
  - Lots of analysis and simulation in the paper

- Upon detection, victim can:
  - Change routing path
  - Switch to multi-path routing
  - Create backup routes to use when performance drops

What about transport protocols other than TCP and UDP?

WSN Transport Reliability

[Buttyán and Csik; PerSens 2010]

- Researchers have proposed many alternative transport mechanisms for WSNs
  - ACK-based approaches, either on an end-to-end or hop-by-hop basis

- Transport-layer attacker
  - Eavesdrops on communications in the network, forges and injects transport-layer control messages
    1. Attacks against reliability
    2. Energy depletion attacks

Protocols Analyzed

- PSFQ – Pump Slowly, Fetch Quickly
  - NACK-based hop-by-hop mechanism to recover from errors quickly by fetching fragments from neighbors
- DTC – Distributed TCP Caching
  - SACK-based hop-by-hop reliability (up- and down-stream) using a combination of ACKs and NACKs
- Garuda
  - NACK-based approach with localized recovery using special-purpose CORE nodes
- RBC – Reliable Bursty Convergecast
  - Window-less ACK scheme for hop-by-hop recovery with efficient out-of-order delivery

General Observations

- ACK/NACK based schemes are vulnerable to control packet injection
  - ACK primarily vulnerable to reliability attacks
  - NACK primarily vulnerable to resource depletion
  - SACK or hybrid ACK/NACK inherit both vulnerabilities
- Preventing resource depletion in NACK-based schemes likely needs strong authentication or well-designed reputation system
- Any protection is subject to trade-offs

Summary

- Transport-layer misbehavior types and potential defenses
  - Jellyfish attacks and protocol-compliant misbehavior in TCP and reliable UDP settings
    - [Aad et al.; MobiCom 2004]
  - Misbehavior in alternative transport protocols for wireless sensor networks
    - [Buttyan and Csik; PerSens 2010]

Mar 17:
Cross-Layer Attack & Defense