Can you fool me? Towards automatically checking protocol gullibility

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Protocol gullibility

Gullibility

tendency to believe too readily and therefore be easily deceived [thefreedictionary.com]

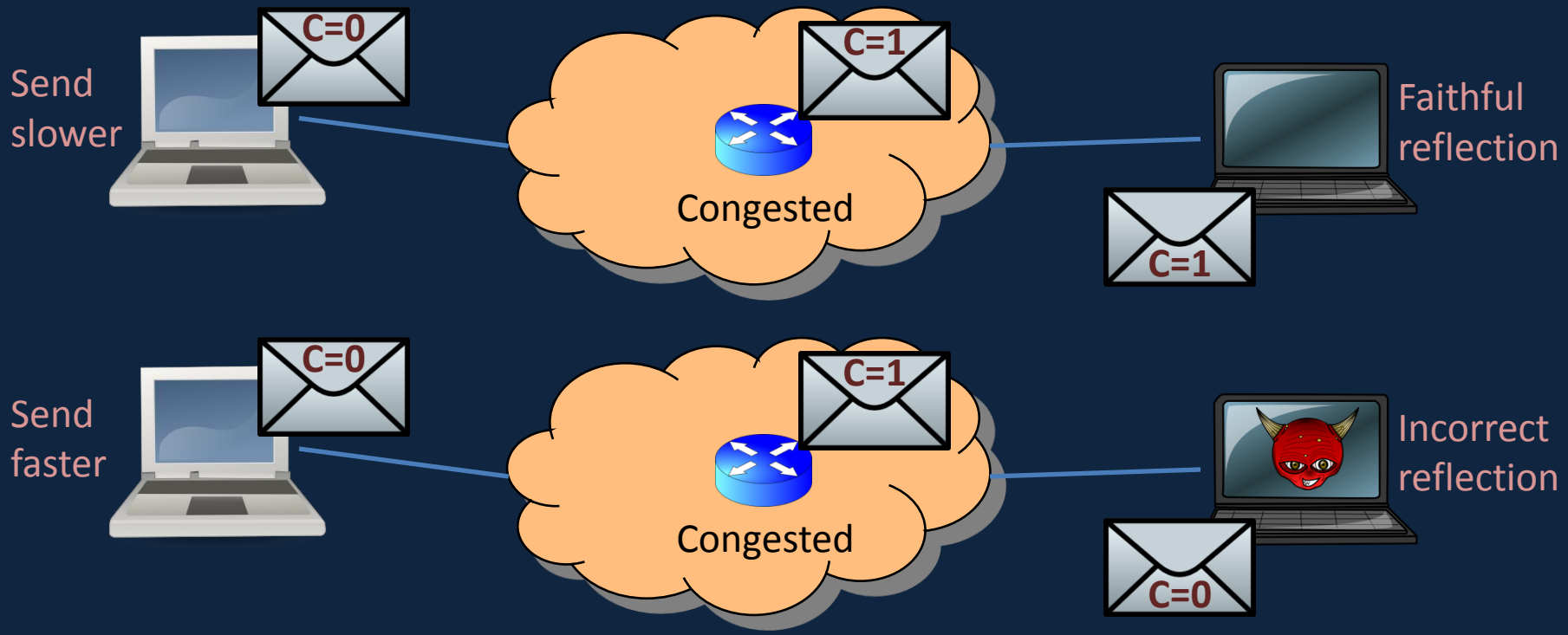
Protocol gullibility

tendency ***of the protocol participants*** to believe too readily and therefore be easily deceived ***by manipulative participants***

- The protocol can be subverted without the knowledge of the honest participants

Gullibility of the ECN protocol

ECN receiver can deceive the sender into sending faster [Wetherall 2001]



More examples of protocol gullibility

TCP receiver can deceive the sender into sending faster

- Three separate manipulation mechanisms [Savage 1999]

Nodes can lie about connectivity in routing protocols

Nodes can refuse to relay packets in multi-hop wireless networks

Several manipulation mechanisms exist for DHTs

Why care about protocol gullibility?

Gullibility is a different form of protocol weakness

- ≠ bugs
- ≠ security problems of auth., integrity, and privacy
- Manipulation by legitimate participants instead of external agents

Gullible protocols fail to achieve their goal in the presence of manipulation

- Modern protocols are regularly used between entities that should not trust each other
- Blind trust is foolhardy: hijacked or buggy participants

Our work

Develop methods to automatically uncover protocol gullibility

This paper represents a baby step:

- Poses and formalizes the problem
- Identifies key challenges and helpful techniques
- Implements a preliminary checker

Problem formulation

Two-player game between *angelic* and *demonic* components

The angelic component consists of honest participants

- Follows the protocol
- Non-determinism is allowed

The demonic component consists of manipulators

- Not limited by the protocol; can do anything
- Collusion is allowed

The protocol is gullible if is there exists a strategy for the demonic component that violates a desirable property

Challenges in determining gullibility

1. Practical search over demonic strategies
2. Determining when a strategy succeeds
3. Dependence on network conditions

Challenge 1: Practical strategy search

The space of demonic strategies

- Any bit-pattern can be sent in a packet
  - 2^{12000} possibilities for a 1500-byte packet
- Some strategies may involve packet sequences

Proposed techniques to make search tractable

- Consider only the header part of the packet
- Consider only syntactically correct packets
- Consider limited-history strategies
- Exploit independence of header fields
- Program analysis (in a few slides)

Challenge 2: Determining when a strategy has been successful

Want to go beyond non-binary properties but hard to predict protocol behavior in arbitrary conditions

- E.g., throughput of a TCP receiver
- Solution: Compare with reference behavior under the same network conditions

Non-determinism precludes direct one-to-one comparison against reference behavior

- E.g., TCP throughput depends on exact packets lost
- Solution: Statistical comparison over multiple runs

Challenge 3: Dependence on network conditions

Some strategies succeed only under particular network conditions

- E.g., the ECN manipulation has no impact in the absence of congestion

Proposed solution:

- Search over the space of network conditions
  - Assume paths between pairs of participants are independent
- Check if the strategy succeeds under any condition

Our preliminary gullibility checker

Checks protocol implementations

- Assumes all headers fields are independent
- Single-step strategies (no history)
- Built on top of MACE [Killian 2005]

Explores angelic non-determinism using simulation

Explores demonic strategies as modifications of the reference implementation itself

- Modify outgoing packets (implemented)
- Add or drop packets (not yet implemented)

Inputs to the checker

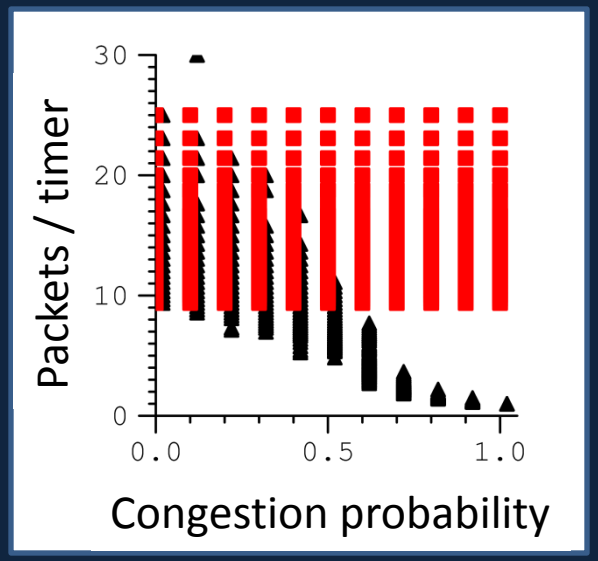
1. Network configuration
2. Properties to be checked
   - Specified in terms of implementation variables
3. Protocol header format
4. A packet modifier class

Field Type	Default strategies for demonic component
Fixed, CkSum	None
Enum, Range	Try each value, pick at random
SeqNum	Subtract or add a constant
Id	Pick at random
Other	User-specified

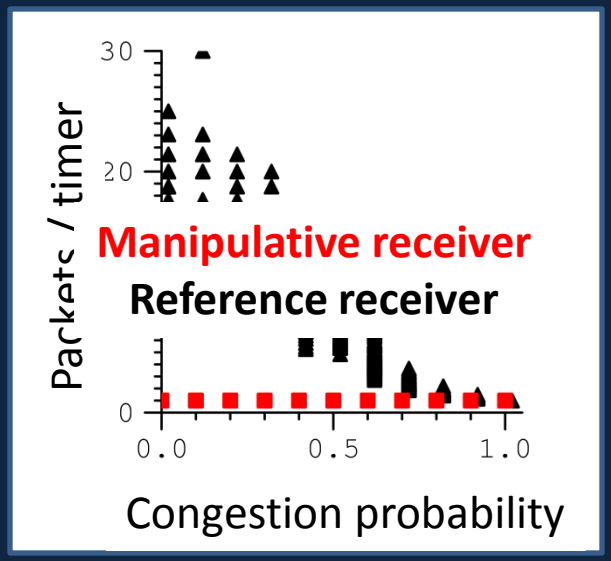
Case study: ECN

We implement a version of the ECN protocol in MACE

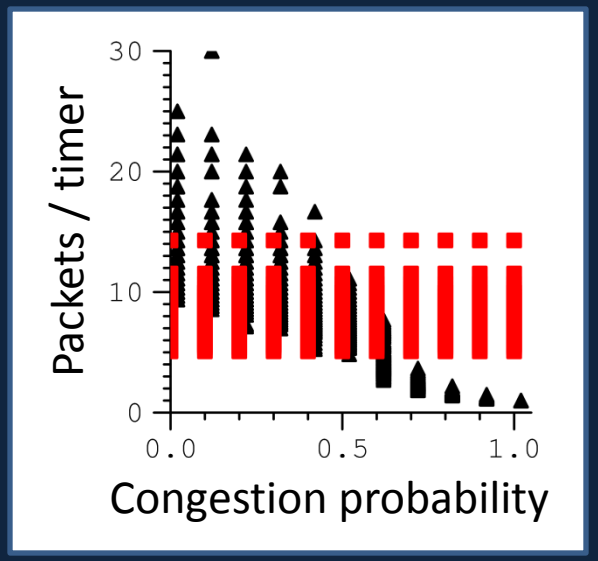
Specify throughput as the property to be preserved



Set bit to 0



Set bit to 1



Set bit randomly

Next: Program analysis to further reduce search space

Infer independent header fields

Infer inputs that are ignored by honest participants

- E.g., If (IP.version != 4) ignore;
- E.g., If (Ack.SeqNum NOT IN CongWin) ignore;

Infer inputs that impact relevant state variables

- E.g., If (Ack.SeqNum > LastSeqNum) pktsSent++;

Hope to leverage work on taint analysis, directed random testing, and symbolic execution

Conclusions and future work

Gullibility is a major vulnerability in modern protocols

- Important to develop methods for automatic detection

Our work scratches the surface of the problem

- Poses the problem and outlines the challenges
- Our preliminary methods show promise

Future work:

- Evaluate more complex protocols
- Design principles for non-gullibility