Security Analysis of MANET in NS2

Giancarlo Pellegrino <gianko@trouge.net>

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"Security in Mobility"

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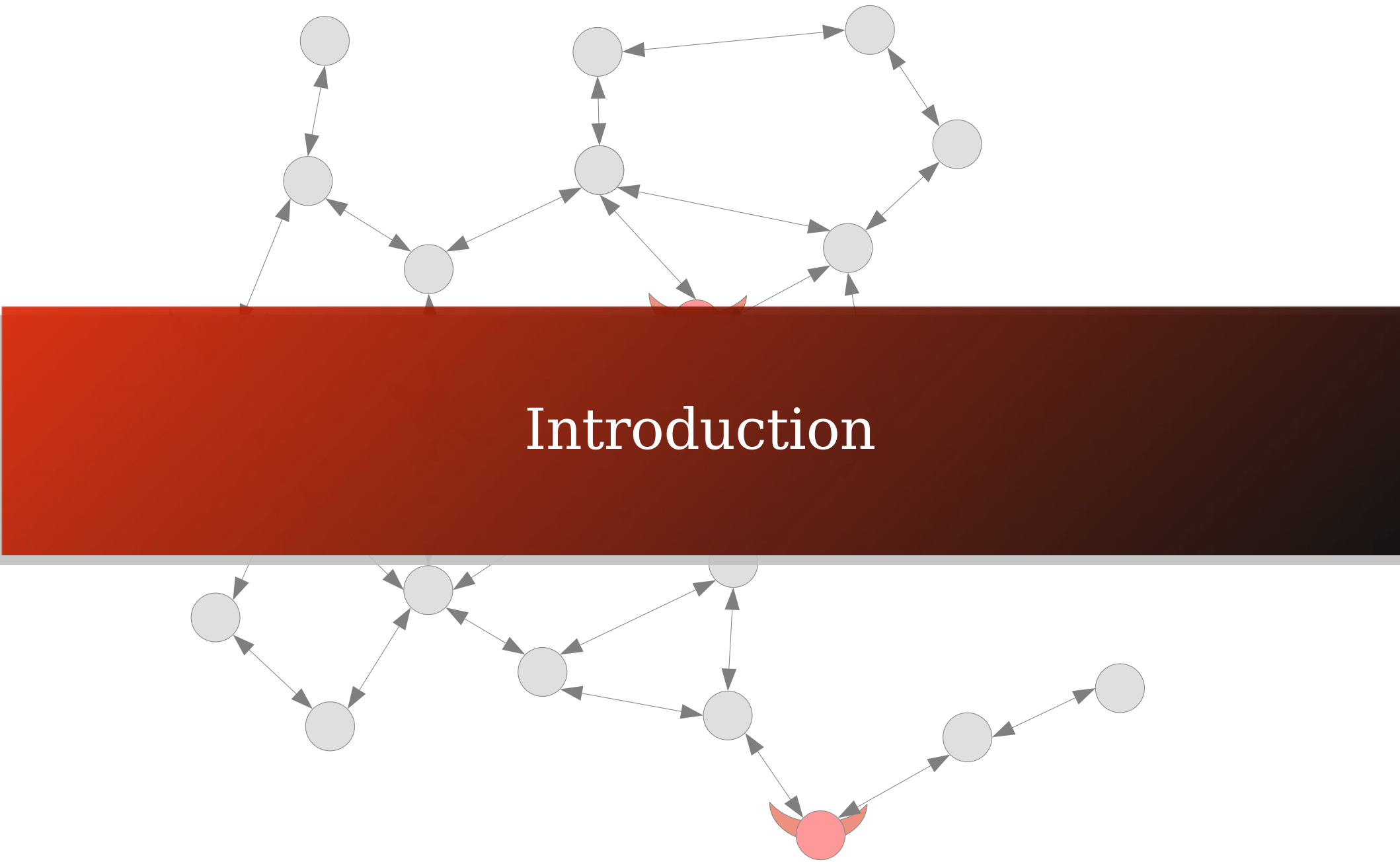


Introduction

MANETs

MANET mean Mobile Ad hoc NETwork or Multi-hop Ad hoc NETwork

- It is a wireless open network;
- a temporary meshed network formed by a collection of mobile nodes;
- a fully self-organized network;
- not rely on any established infrastructure for the network initialization and operation;
- initially envisioned mainly for crisis situation (e.g. battlefield or rescue situation) ...
- ... subsequently (due to low-cost devices 802.11) for civilian applications (e.g. VANET)

MANETs

Other features:

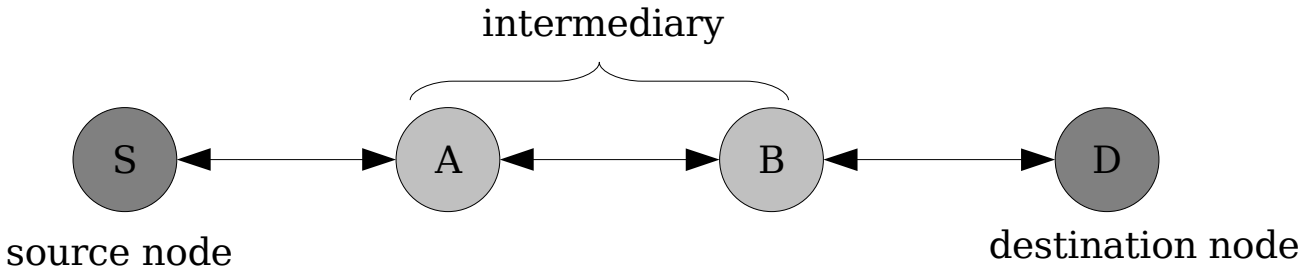
- **Multi-Hop**: due to limited transmission range**;**
- **Distribuited approch**: lack of infrastructure to support network operation;
- **Dynamic topography**: MANET entities are mobile nodes;
- **Nodes cooperation**: basic operations are performed by whole community;
- **Peer-to-Peer (P2P) analogies**: that is a community, composed by peer entities (mobile nodes), which share a common resource (network services).

Basic network operations

Basic network(-level) operations

Basic operations are carried out using a distribuited approach:

- **Packet forwarding**: e.g. a source node S send packets to a destination node *D* through a path *<S, A, B, D>*. Nodes A and B will perform **p.f.** function to deliver packets.
- **Routing**: e.g. a source node S receive aid from community to discover a route to node *D*.



Security analisys

Background

The differences between MANETs and infrastructured networks make useless whole known network concept.

Inadaptability of:

- known “classic” routing protocols for wired networks;
- security systems which offers authentication, confidentiality, integrity and non-repudation.

Then MANETs describes a new network paradigm: **Ad Hoc Paradigm**.

Features hide lacks

- **lack of physical and network layer security**: vulnerabilities such as traffic subversion/redirection, network partition, spoofing etc...;

- **lack of a-priori trust**: mobile nodes are not part of any shared organizzation. Classical security mechanisms based on preestabilished trust are not applicable;

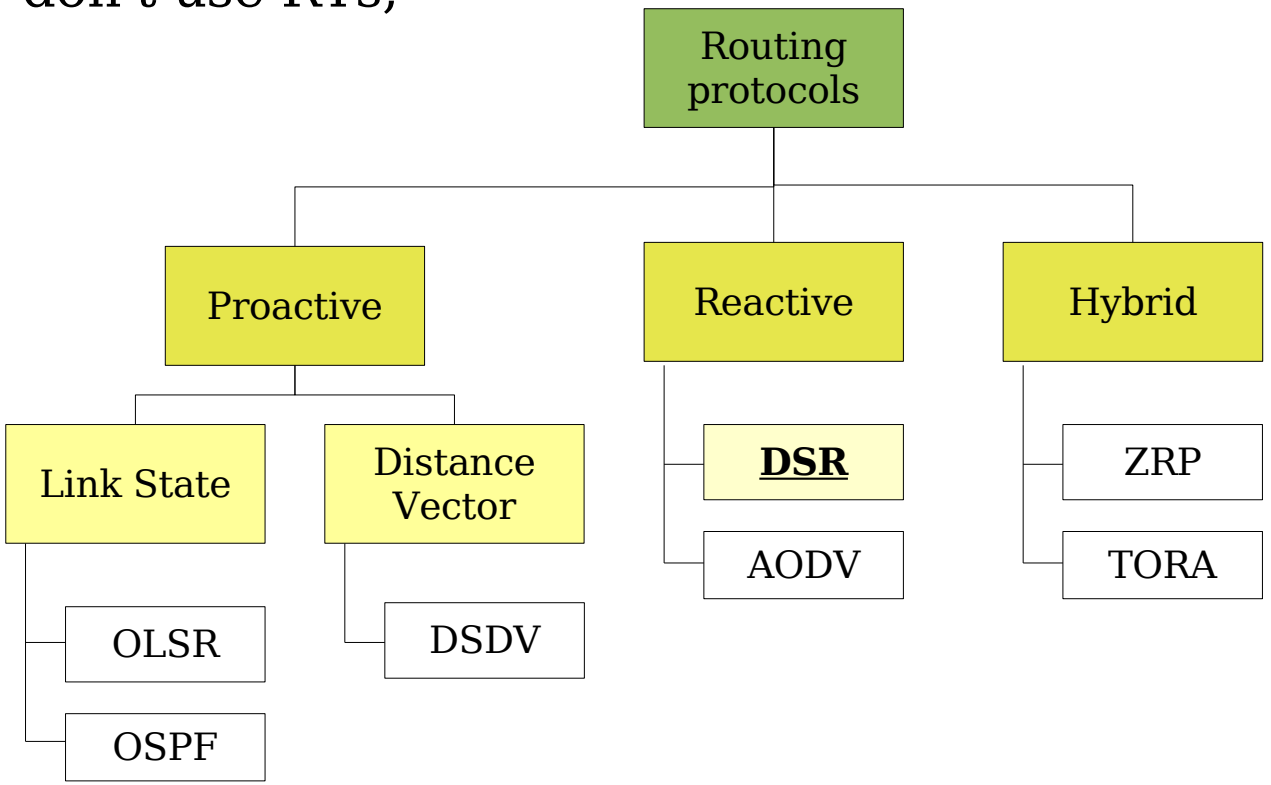
- **lack of infrastructure**: other operation such as *Key Servers* and *Trusted Third Parties* (TTP) are not compatible with **Ad Hoc Paradigm**;

- **requirement for cooperation**: due both to lack of dedicated components for network operations.

Routing protocols

Families protocols:

- **Proactive**: use messages to populate RTs;
- **Reactive** (o On-Demand): don't use RTs;
- **Hybrid**;
- ...;



Routing protocols assumes collaboration between nodes: **lacks of security mechanisms**.

Routing protocols

Reactive protocol embody ad hoc networks features.

- **Ad hoc On-demand Distance Vector** (AODV - RFC3561) take benefit of dynamic Routing Table (RT) and Bellman-Ford algorithm;
- **Dynamic Source Route** (DSR): fully On-Demand, don't use RT but it has a Route Cache and SendBuffer to store outgoing packets. Main procedures: **Route Discovery** and **Route Maintenance**.

Attacks

MANETs vulnerabilities and lacks give rises attacks at network layer of ISO/OSI stack.

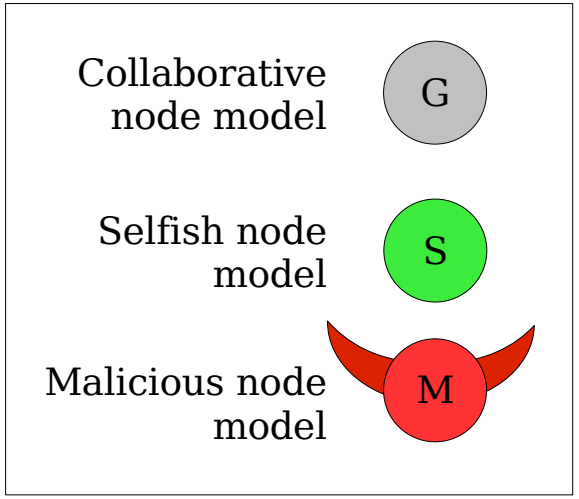
- **Active attacks**: that requires energetic cost;
- **Passive attacks**: are perpetrated by nodes that not cooperate to save battery life.

Node behaviours identify attacks...

Attacks

Behaviour node models

- **Collaborative model**: a node that behave properly executing both p.f. and routing functions;
- **Selfish model**: a node that misbheave to save its battery life. This node could disable p.f. and/or routing functions;
- **Malicious model**: a node that aim at damaging other nodes by causing network outage by partitioning while saving battery life is not a priority.



Passive attacks

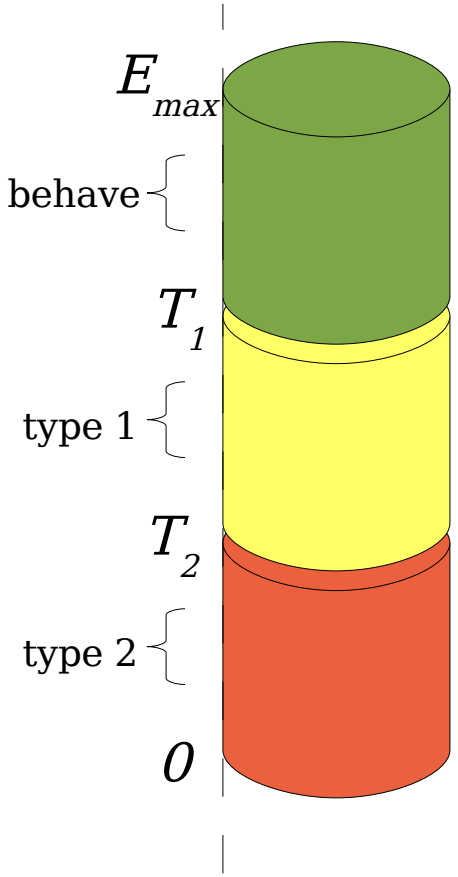
Selfish node models

- **Type 1**: node does not perform the p.f. function;
- **Type 2**: node does not perform the routing function (DSR or AODV);
- **Type 3**: the node behaviour follows an energy model:

  - when $E_{max} =< E_{curr} < T_1$ node behaves properly;

  - when $T_1 =< E_{curr} < T_2$ node behaves as if it was a selfish node of type 1;

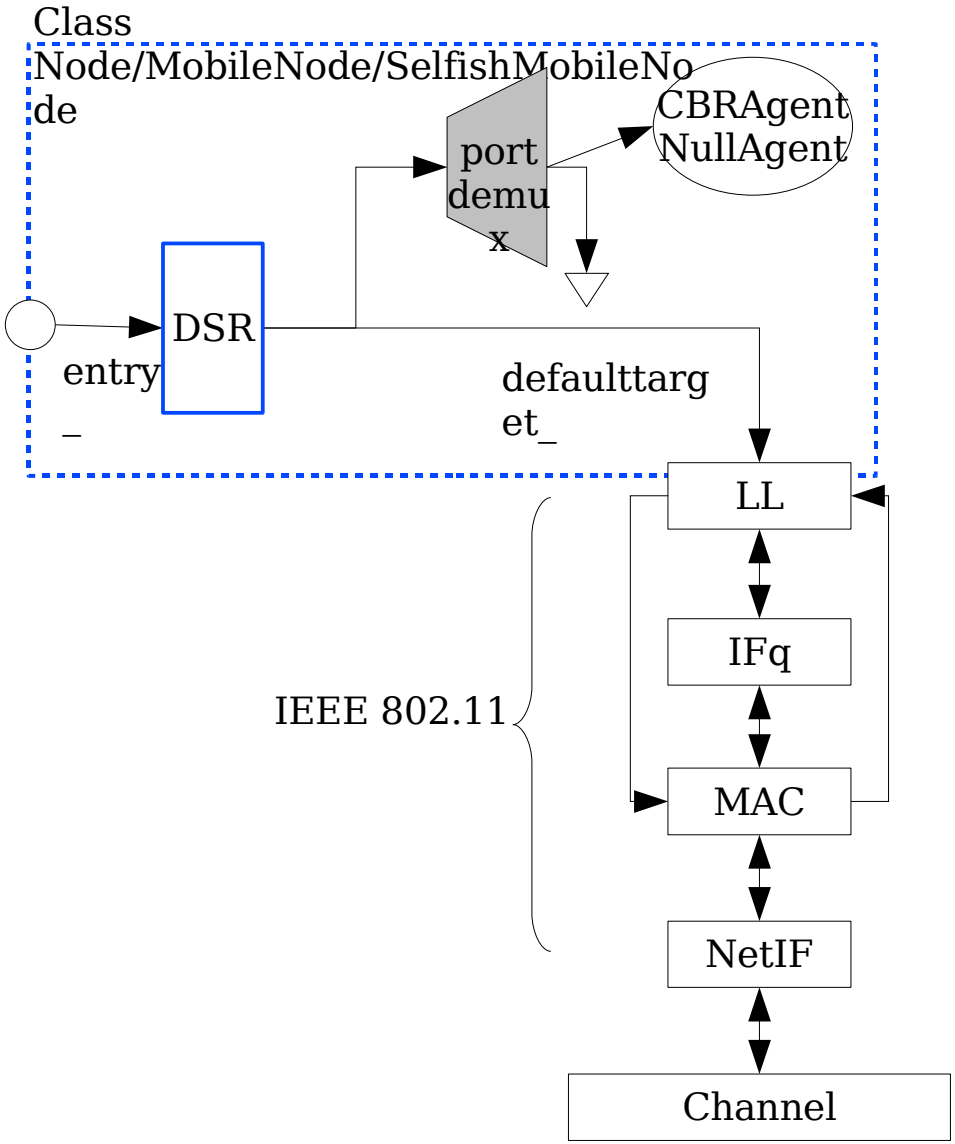
  - when $T_2 =< E_{curr} < 0$ node behaves as a selfish node of type 2.



Passive attacks

ns2 components

- **SelfishMobileNode**: new Otcl class representing selfish mobile nodes of type 1 or 2;
- **DSRAgent**: modified to perform selfish misbehaviours;



Passive attacks

Performance metrics

- **Throughput**: def. $T = \frac{r_a}{g_a}$
- **Overhead**: def. $O = \frac{d_a + s_n}{g_a}$

r_a: tot. # of received packets at application layer

g_a: tot. # of generated packets at application layer

d_a: tot. # of lost packets at application layer

s_n: tot. # of sent packets at network layer

Passive attacks

Simulations in NS2

6 families of simulations depicted by:

- **Density**: low = 20 nodes, high = 60 nodes;
- **Mobility**: low = 2 m/s, high = 15 m/s
- **Selfishness**: type 1 or type 2

Parameters:

- nodes deployed over an 800 by 800 flat meter space;
- percentage *p* of selfish nodes takes values from *p=0%* to *p=50%*;
- random waypoint model;
- costant bit rate; packets size = 512bit; packet rate = 1 packet/s
- protocols: **IEEE 802.11**, **IP**, **UDP** and **CBR**

Passive attacks

Launcher and analyser

Launcher:

- gived the family, for each percentage p build 40 different MANET models;
- 19Gb of trace files;
- produced about 5.400 different models of MANET.

Analyser:

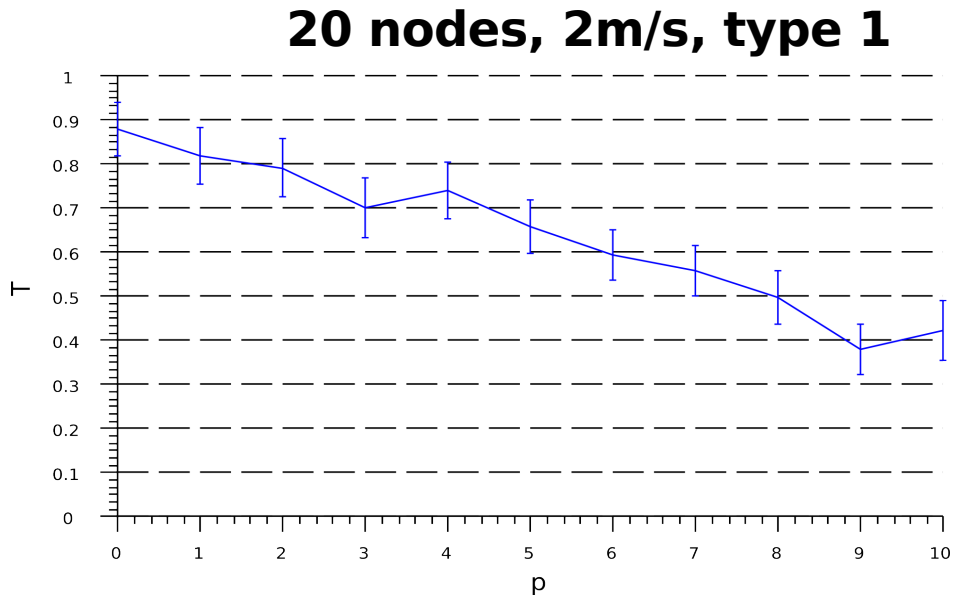
- calculate T, O, r_T and r_O (radius of confidence interval at 95%)
- produce graphs.

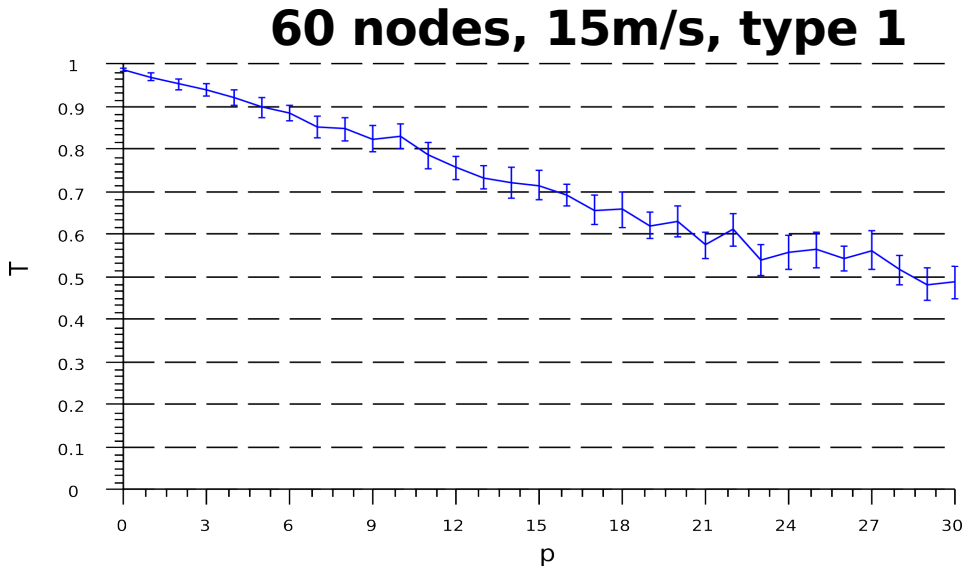
Passive attacks

Results (1/3)

Throughput **type 1**:

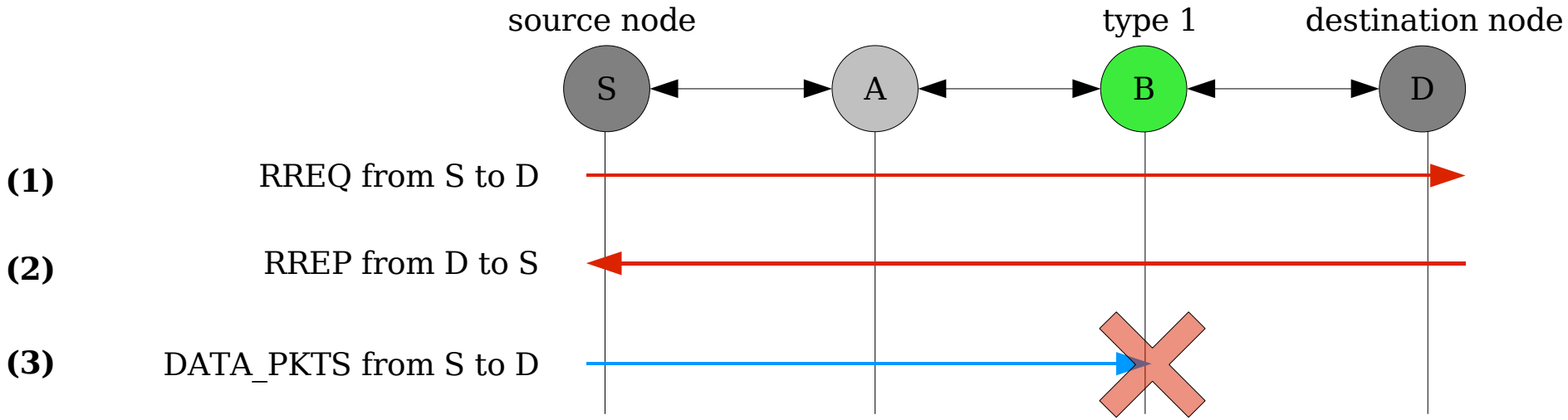
- degrades by 60% when 50% of the modes mishbehave;
- node mobility and density have a negligible influence on the measurements.





Passive attacks

Observations (1/3)



$$T = \frac{r_a}{g_a}$$

Linear regression from 0% to ~60%

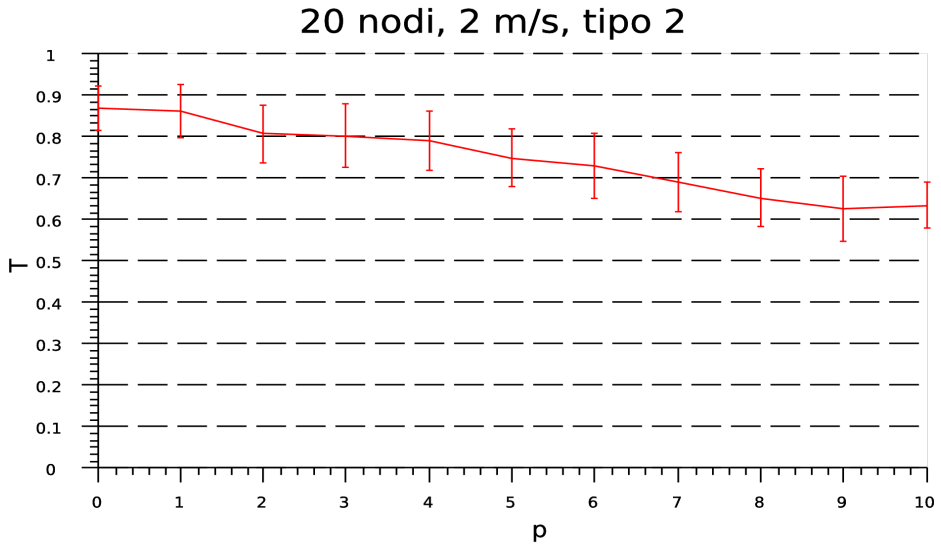
Passive attacks

Results (2/3)

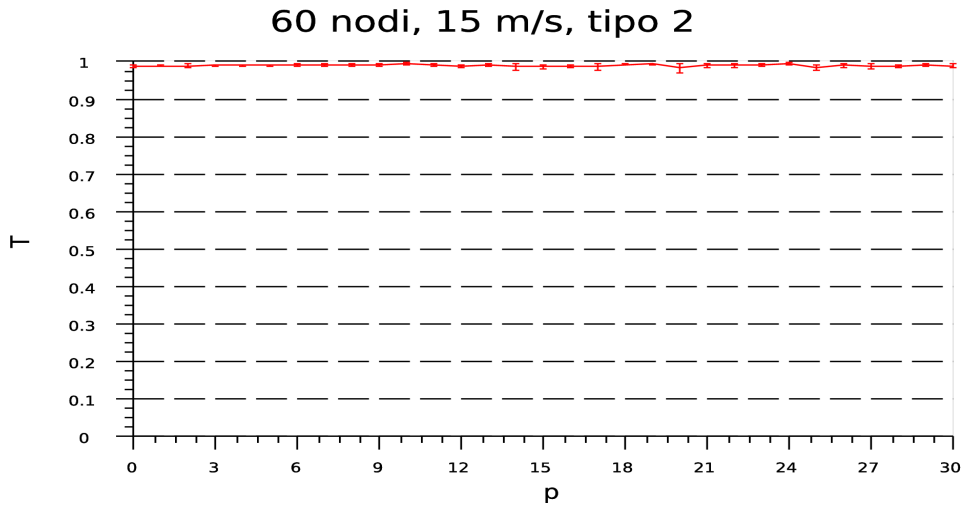
Throughput **type 2**:

- with low density degrades by ~40% when 50% of the nodes misbehaves;
- node density improve network throughput.

20 nodes, 2m/s, type 2

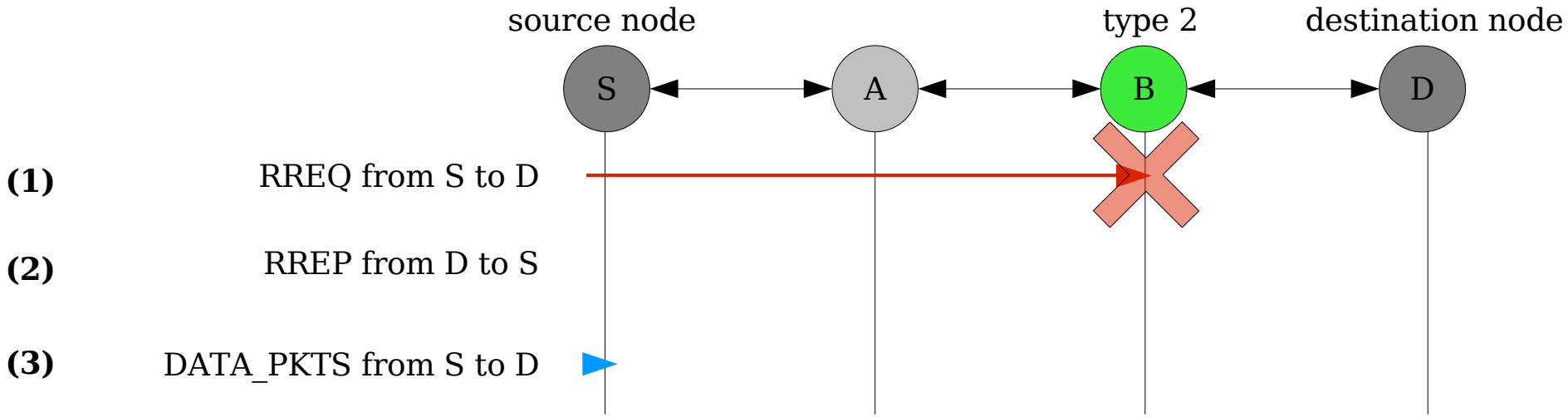


60 nodes, 15m/s, type 2



Passive attacks

Observations (2/3)



$$T = \frac{r_a}{g_a}$$

1) Linear regression from 0% to ~40% with low density and low mobility

2) Improve with high density and high mobility

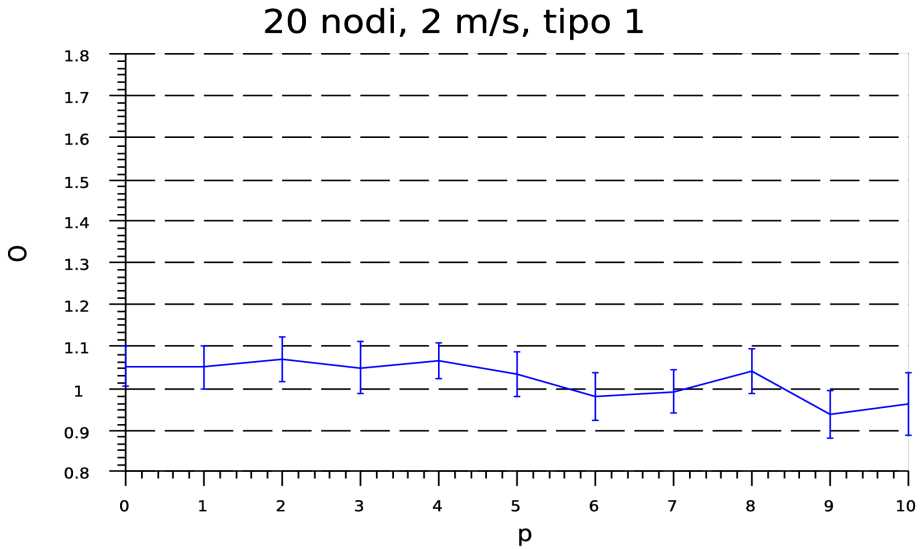
Passive attacks

Results (3/3)

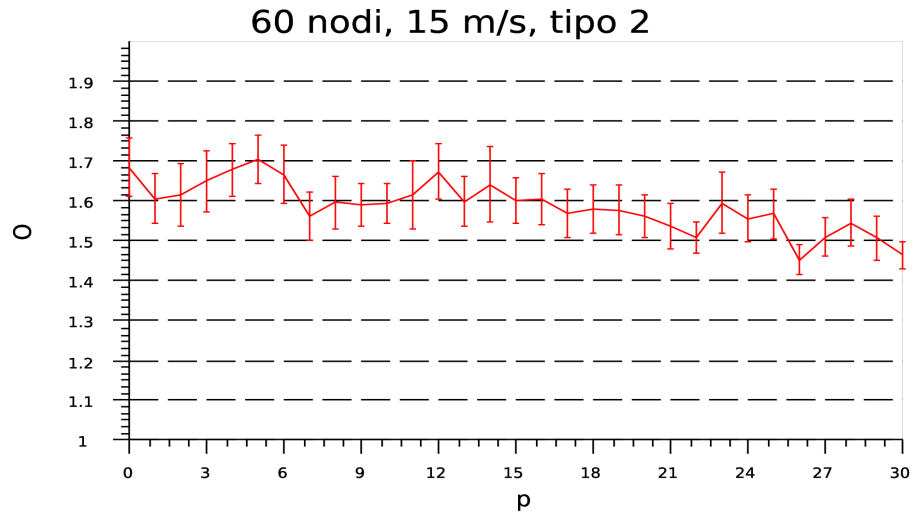
Overhead **type 1** & **2**:

- degrades slowly when p increase
- nodes density and mobility increases # of packets inside the network

20 nodes, 2m/s, type 1

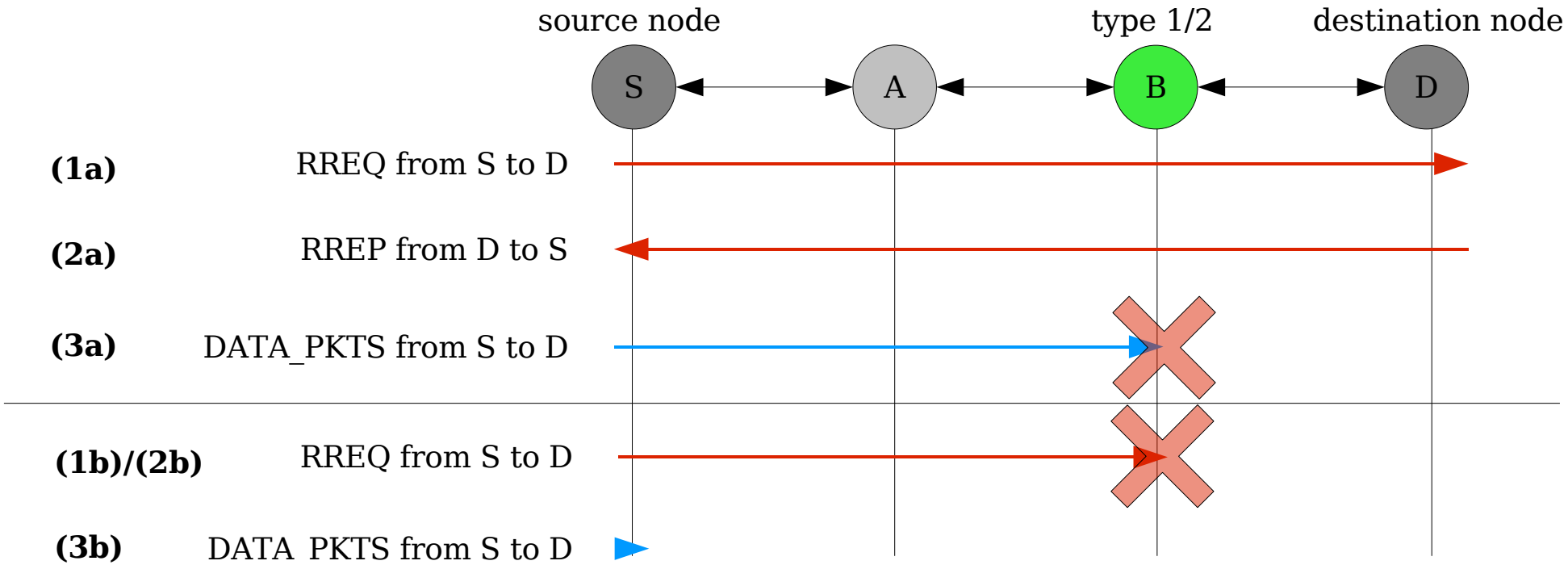


60 nodes, 15m/s, type 2



Passive attacks

Observations (3/3)



$$O = \frac{d_a + s_n}{g_a}$$

- O<2 => for each packet sent by CBRAgent there are at the worst 2 packets
- O>1 => simulations reach the term while there are still packets in SendBuffer.

Active attacks

Smashing the MANET for fun and profit

Def: attack carried out in order to withhold the normal network operation by compromising the routing protocol.

Classification:

- Threats using **modification**: due to lack integrity checks;
- Threats using **impersonation** (a.k.a. spoofing attacks): due to lack of authentication at network/datalink layer;
- Threats using **fabrication**;

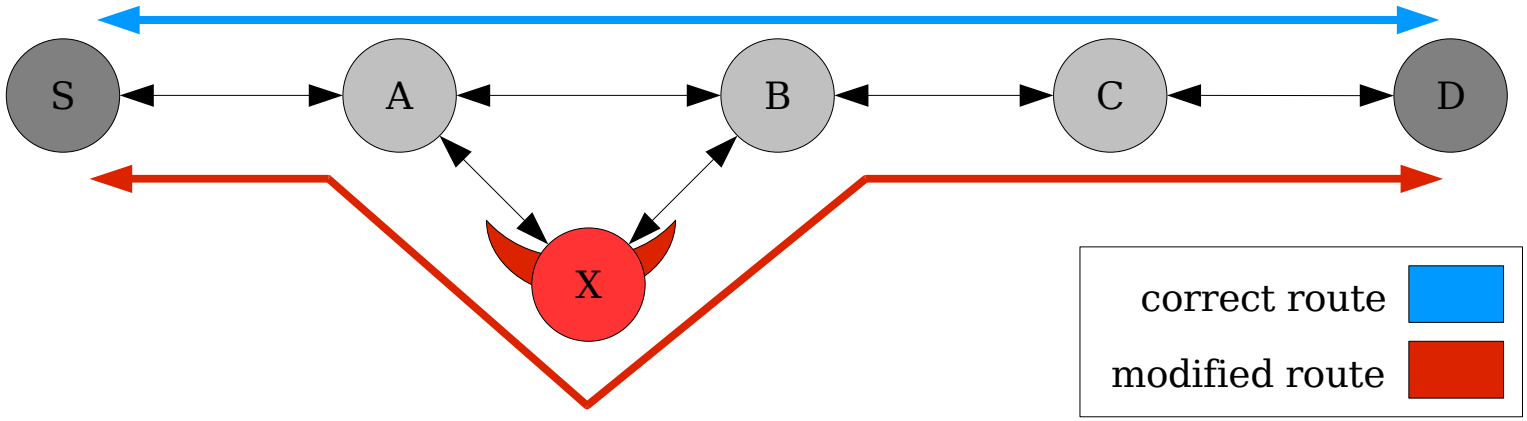
Active attacks

Redirection with modified sequence number

In AODV any node may divert traffic:

- S send a RREQ to its neighbours (A) for destination D
- A forward RREQ to X and B
- X unicast a false RREP to A containing an higher *dest_sequence_num* for D

Then X belong to shortest path from S to D

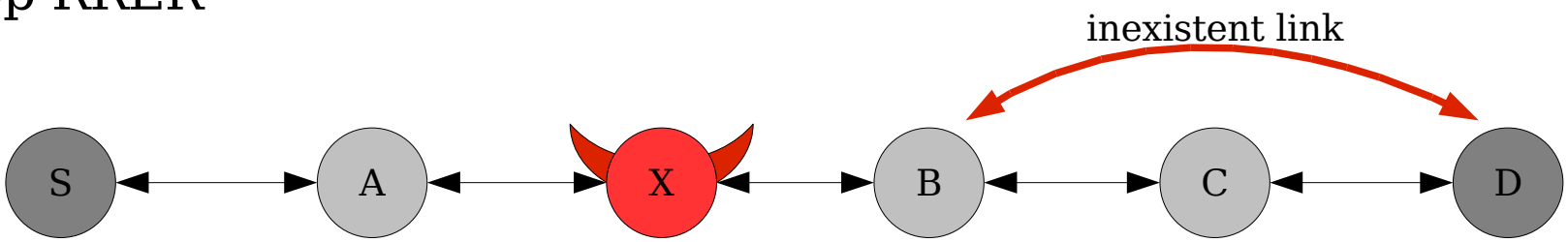


Active attacks

Denial of Service with modified source routes

In DSR states routes in data packet:

- suppose that D hear C, and B hear X
- S send data for destination D using source route <S, A, X, B, C, D>
- A forward packets to X
- X alter source route <S, A, X, B, C, D> in <S, A, X, B, D>
- B send a RRER (link broken) to source S
- X drop RRER



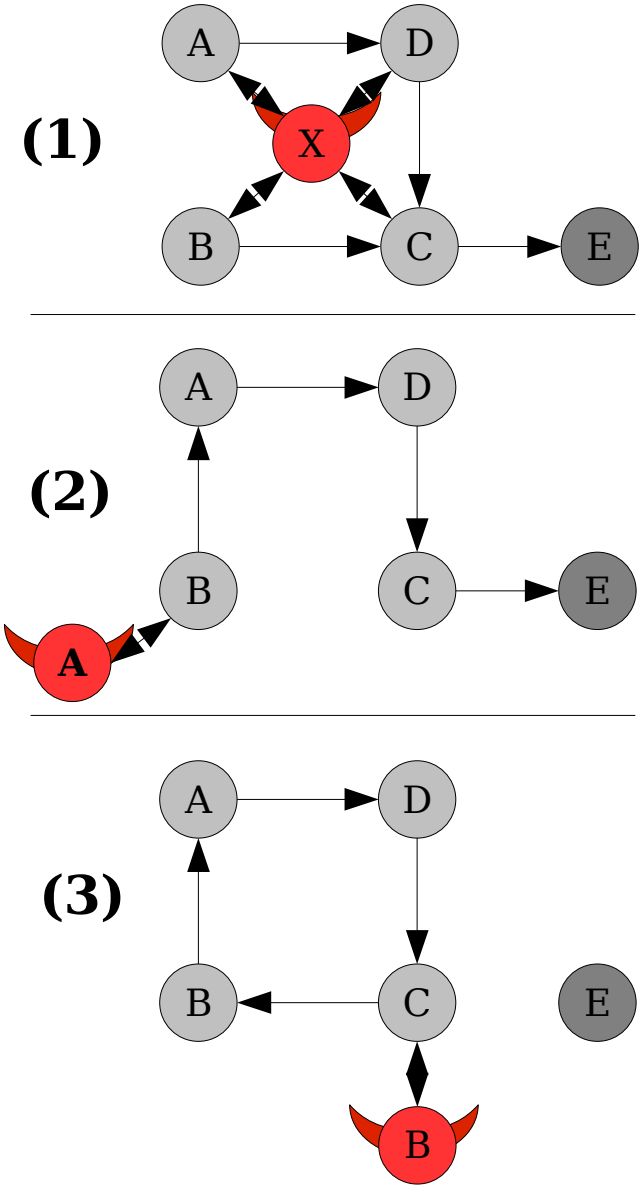
Active attacks

Forming loops by spoofing

In AODV may happen:

- (1) X learn the topology by listening;
- (2) X move closer to B and change its MAC address in S's ...
- ... X send RREP to B that contains a hop count to E less than the one sent by C
- (3) X move closer to C and change its MAC address in B's ...
- ... X send RREP to C that contains a hop count to D lower than the one sent by E

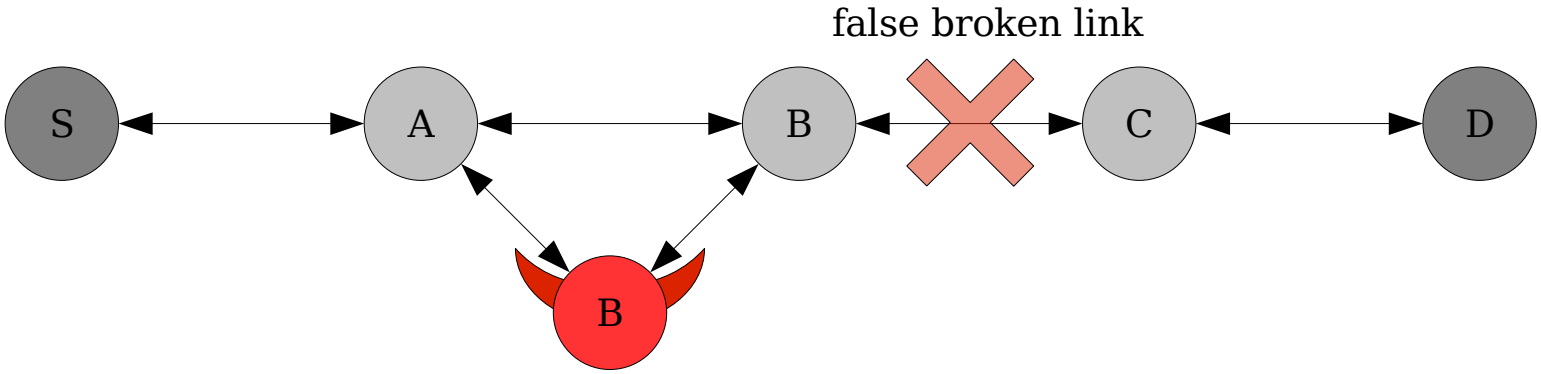
Then E is isolated.

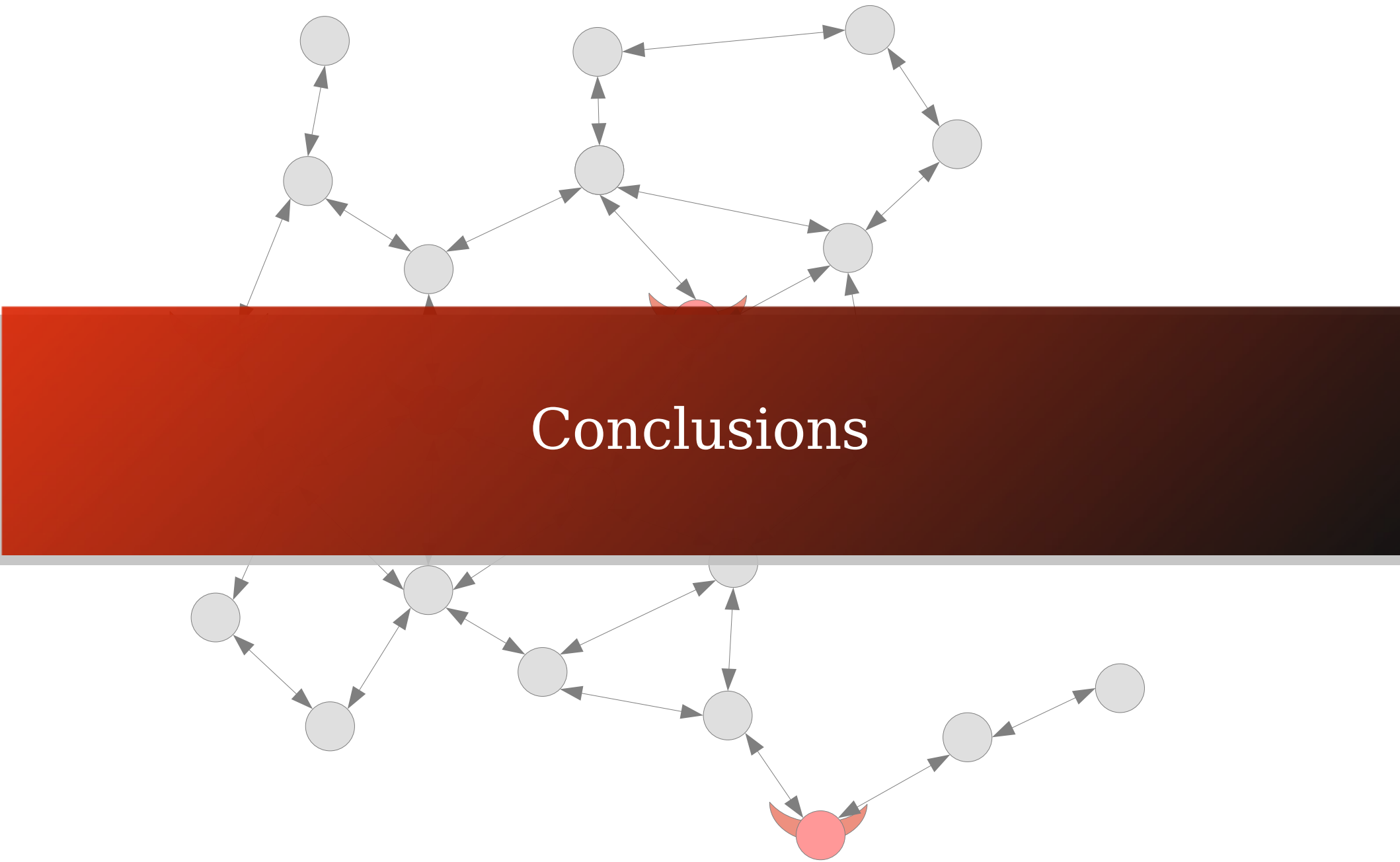


Active attacks

Falsifying RRER messages in AODV and DSR

- Suppose node S has a route to D: <S, A, B, C, D>
- a malicious node X can launch DoS attack against D by sending RRER messages to A spoofing node B





Conclusions

Conclusions

Passive attacks:

- Necessary and sufficient condition is cooperation between nodes;
- The network performance severely degrade when a large percentage of node do not cooperate in p.f. function;

Then: need to enforce collaboration between nodes

Active attacks:

- Routing protocols do not care of security aspect;

Then:

- Need of securing routing protocol;
- Need of authentication mechanism to prevent spoofing attack;
- Need of integrity of routing messages;

MANETs:

- represent a challenging scenario for researchers;
- will play an important role in society and economy.

TODO:

- carry out studies upon impact of selfishness of type 3;
- recuring routing function;
- ...

The end

References:

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