A Game Theoretic Approach for Securing AODV in Emergency Mobile Ad Hoc Networks

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Roadmap

- PEACE project & eMANETs
- Emerging Game
- AODV-Game Theoretic (AODV-GT) module
- Mission Critical Mobility
- Performance Evaluation
- Conclusions

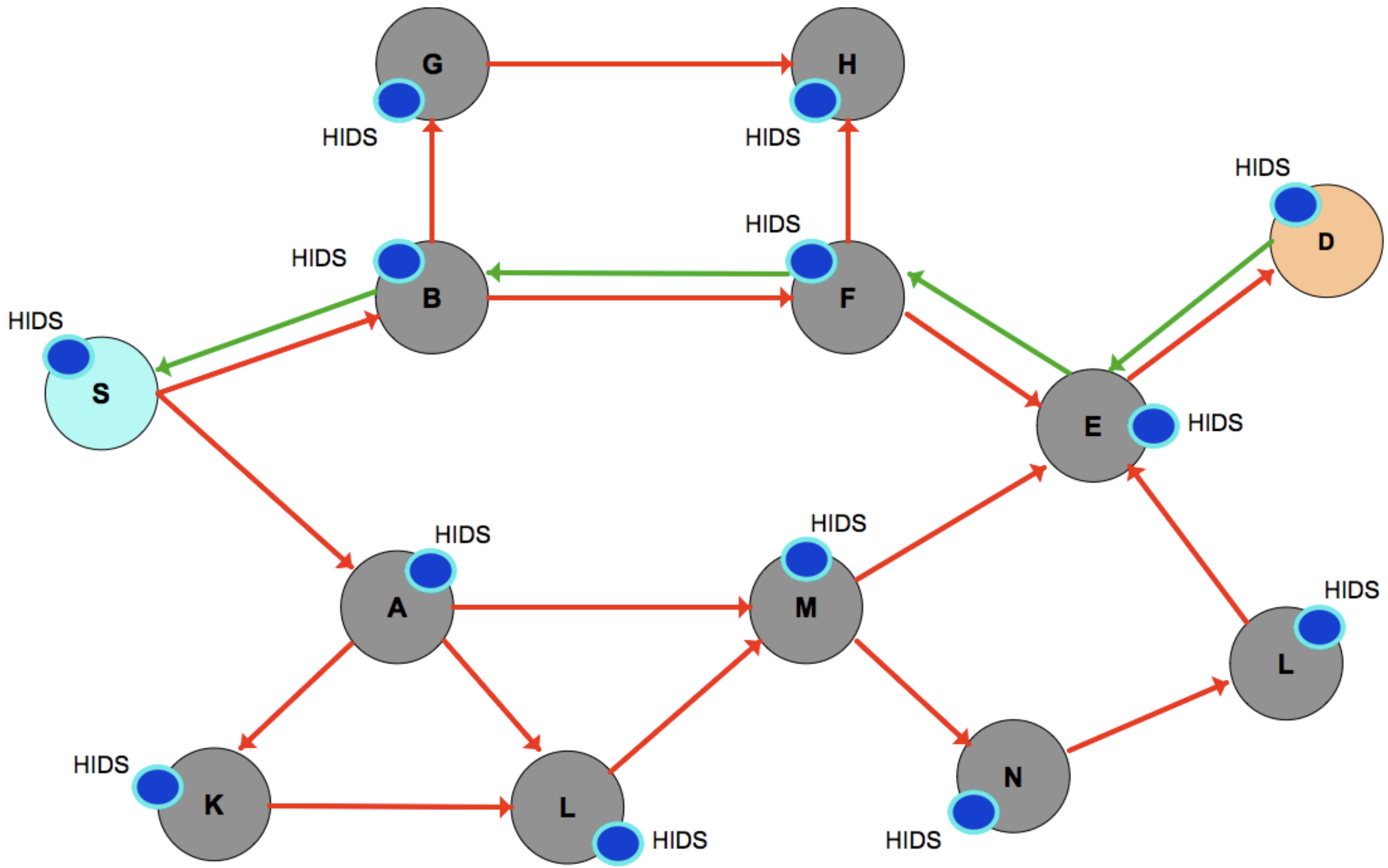
PEACE project & eMANETs

- ICT EU FP7 Project (http://www.ict-peace.eu/)
- Disaster Recovery Teams
- Secure Mobile Ad hoc Communications

Definition of the game

- Two-player non-cooperative security games
- Players: MANET, malicious nodes
- MANET defends against blackhole nodes by using Host Intrusion Detection Systems (HIDSs)
- Blackhole nodes succeed to attract the data traffic and drop packets

Example



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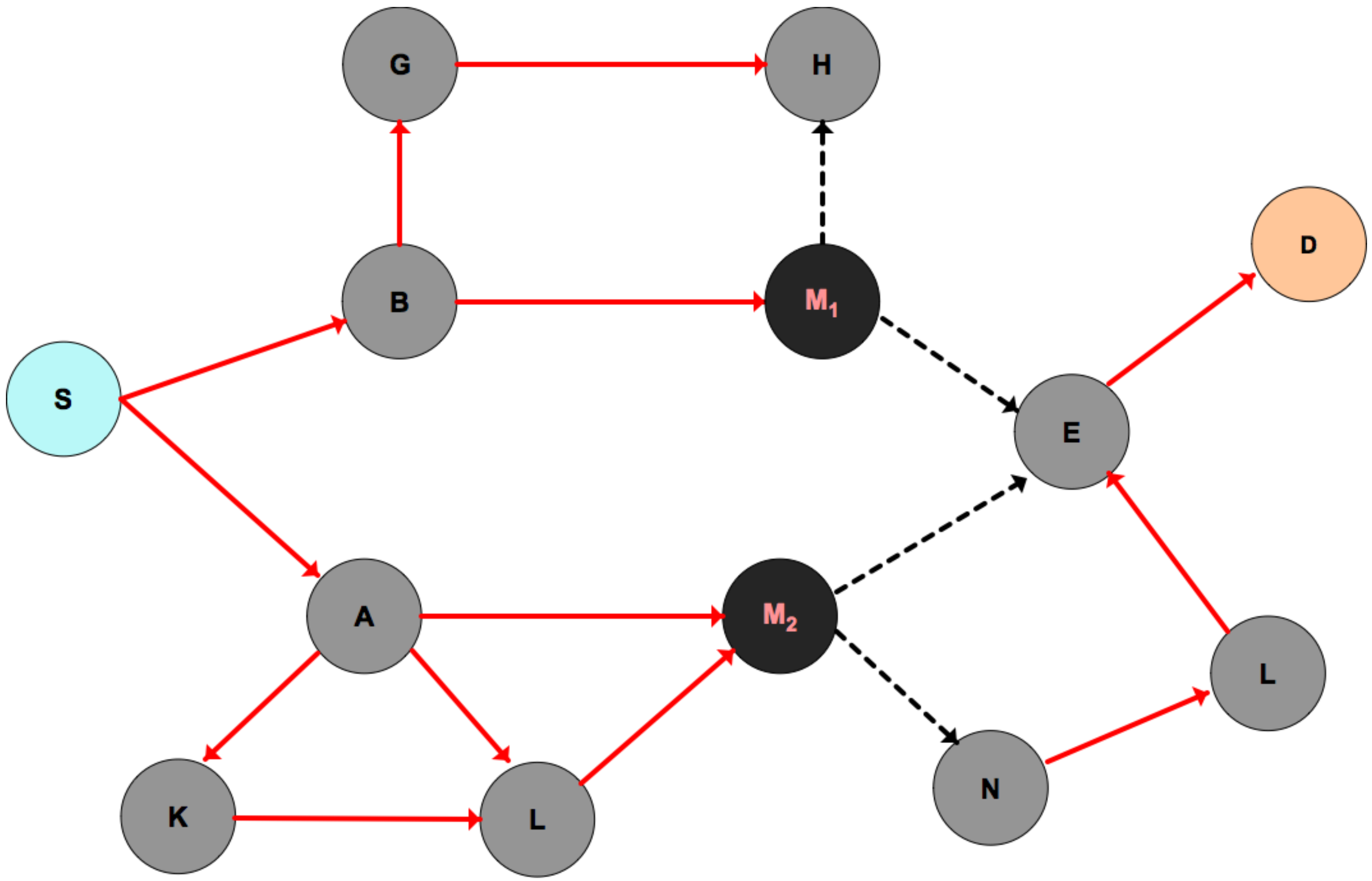
Example



Strategy space

- MANET:
  - d_i: the MANET defends a route i
  - d_{-i}: the MANET defends any other route $-i$.
- Any blackhole node:
  - m_i: the blackhole node attacks a route i
  - m_0: the blackhole node does not attack MANET
  - m_h: the blackhole node attacks a route h.

MANET payoff matrix

$U(t)$

$PD(t)$: the utility of the MANET at time *t*

DC_i : the cost per hop of defending a route *i*

FC_i : the cost per hop of failing to protect a route *i*

s.t.	m_i	m_0	m_h
d_i	$PD(t) - DC_i$	$PD(t) - DC_i$	$PD(t) - DC_i -$ $-FC_h$, for $h \neq i$
d_{-i}	$PD(t) - DC_{-i} -$ $-FC_i$	$PD(t) - DC_{-i}$	$PD(t) - DC_{-i} -$ $-FC_h$ for $h \neq i, -i$

$$DC_i = \frac{\sum_{j \in i} nn_j}{n_i} \qquad FC_i = \frac{\sum_{j \in i} dens_j}{n_i} \qquad dens_j(R) = \frac{N R_j^2 \pi}{A}$$

nn_j : the number of one-hop neighbors of node *j*

i : a node that belongs to the route *i*

n_i : the number of nodes constitute the route *i*

- *N* : the number of nodes within the transmission range of a node *j*
- R_j : the transmission range
- *A:* the area of the MANET

Attacker payoff matrix

s.t.	m_i	m_0	m_h
d_i	$PA(t) - CA_i$	0	$PA(t) - CA_h$, for $h \neq i$
d_{-i}	$PA(t) - CA_i$	0	$PA(t) - CA_h$, for $h \neq i$

CA_i : is the cost of attacking a route *i*

$PA(t)$: is the profit of each successful attack at time *t*

Nash Equilibrium

- at NE: MANET defends the route with the highest $P(t) - DC_i$ value
- max $P(t) - DC_i$ → min DC_i
- any blackhole node prefers to attack the MANET instead of receiving zero utility

The strategy pair (d_1, m_1) is the NE of the game because is the dominant strategy of the non-zero sum game

AODV-Game Theoretic

- AODV is a reactive routing protocol for MANETs
- AODV-GT modifies/ extents the AODV to select routes in a way that the NE of the aforementioned game is achieved
- extension of AODV to carry the utility value $u_A = \frac{1}{nn_A}$ of each node A

$nn_A \longrightarrow$ **the number of one-hop neighbors of node *A***

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  $nn_A \longrightarrow$ **the number of one-hop neighbors of node *A***
- each node which receives a RReq adds the utility value to the packet
- source derives the average utility value of each route as

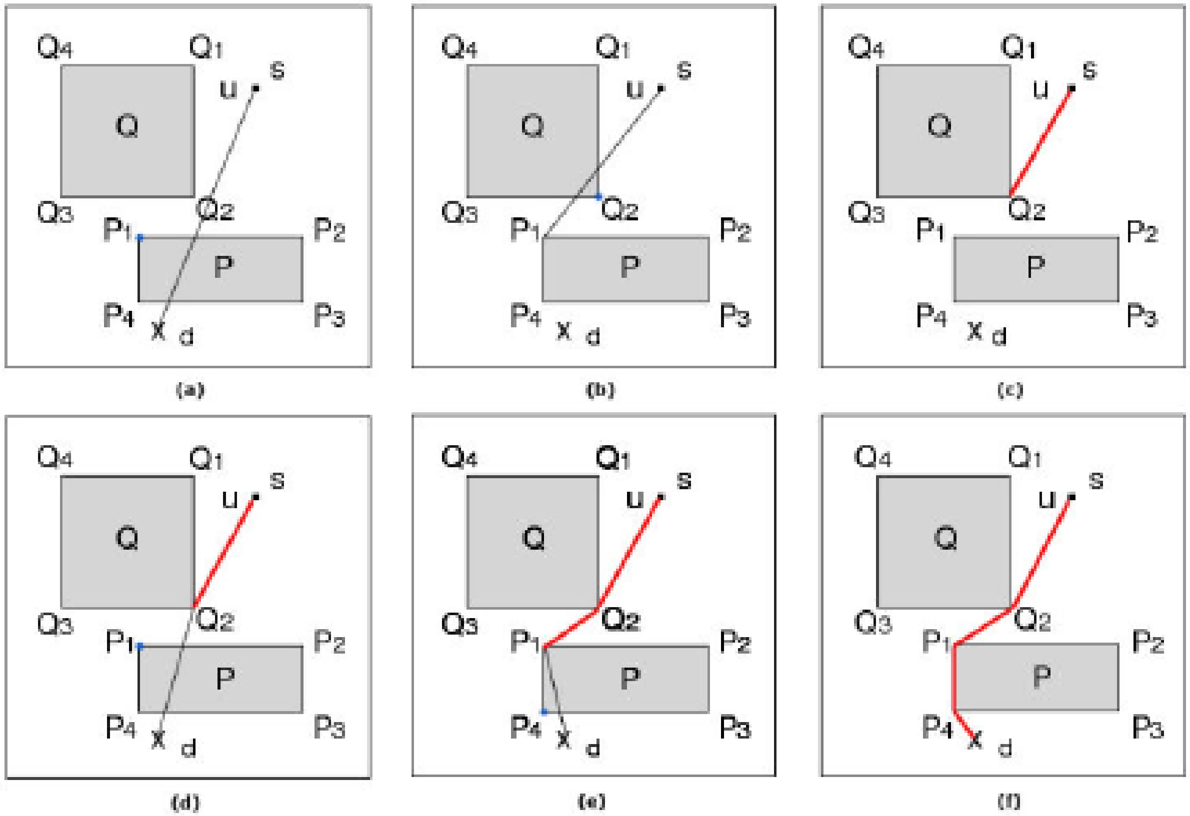
$$\bar{u_i} = \frac{nhops_i + 1}{\sum_{j \in i} nn_j}$$

$nhops_i$: number of hops in route *i*

AODV-Game Theoretic (2)

- source chooses the route with the maximum average utility
- Why ???
  - At NE: min DC_i ⟶ max $\bar{u_i}$ $$DC_i = \frac{\sum_{j \in i} nn_j}{n_i}$$
  - This route is the most secure and cost effective route in terms of HIDS sensors resource consumption
  - Why most secure ???
    - The attacker prefers probabilistically to place himself in an area where the nodes' density is high
      - min DC_i happens when the density of the chosen route's nodes is low
  - Why cost effective in terms of HIDS resource consumption ???
    - At the NE less HIDSs participate in the intrusion detection

Mission Critical Mobility

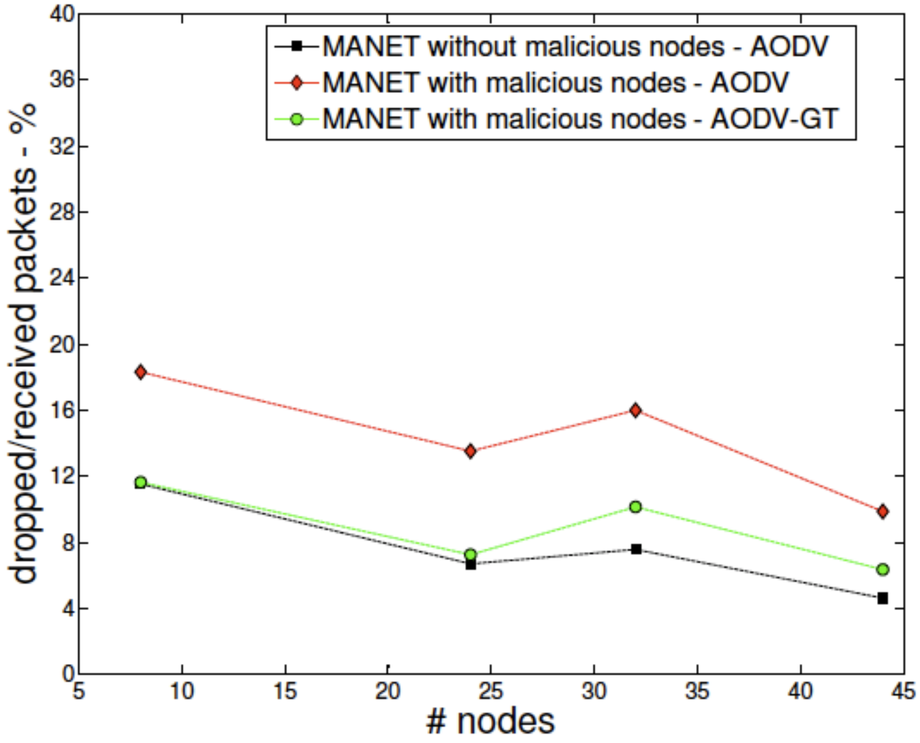


- simulates the movement of nodes during an emergency case in presence of obstacles (extension to network simulator ns-2)

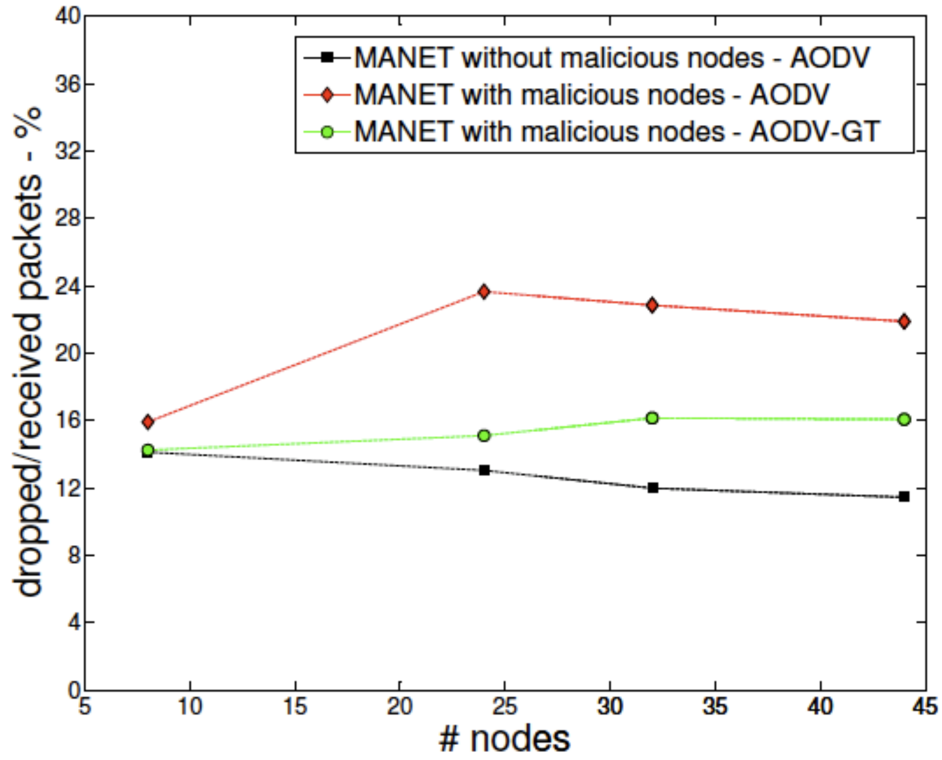
Simulation Results (1)

UDP traffic, 1000m x 1000m

v = 1 m/s



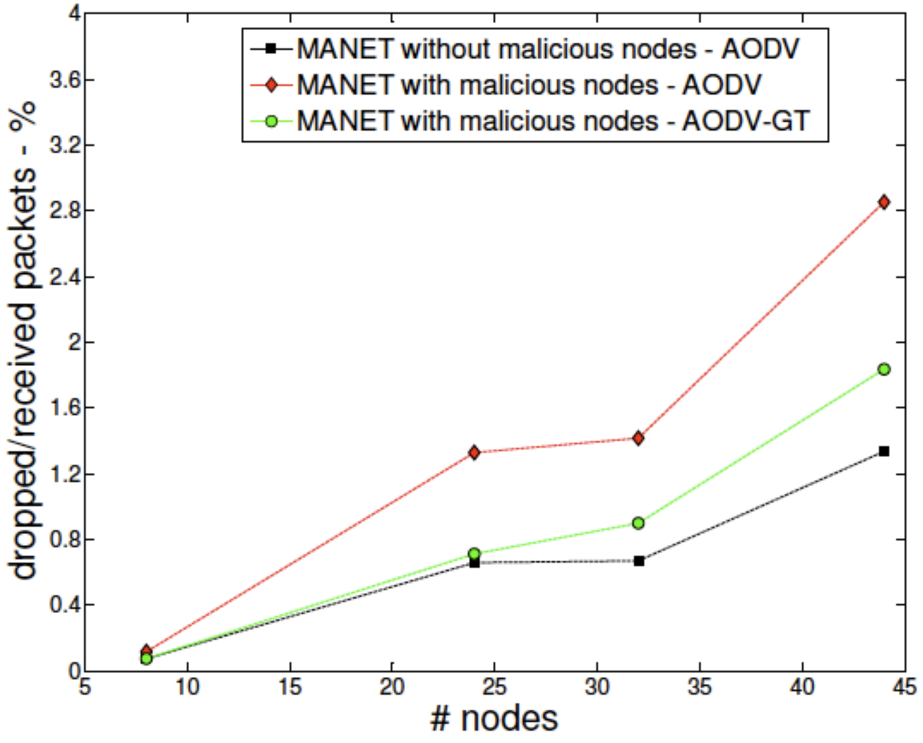
v = 5 m/s



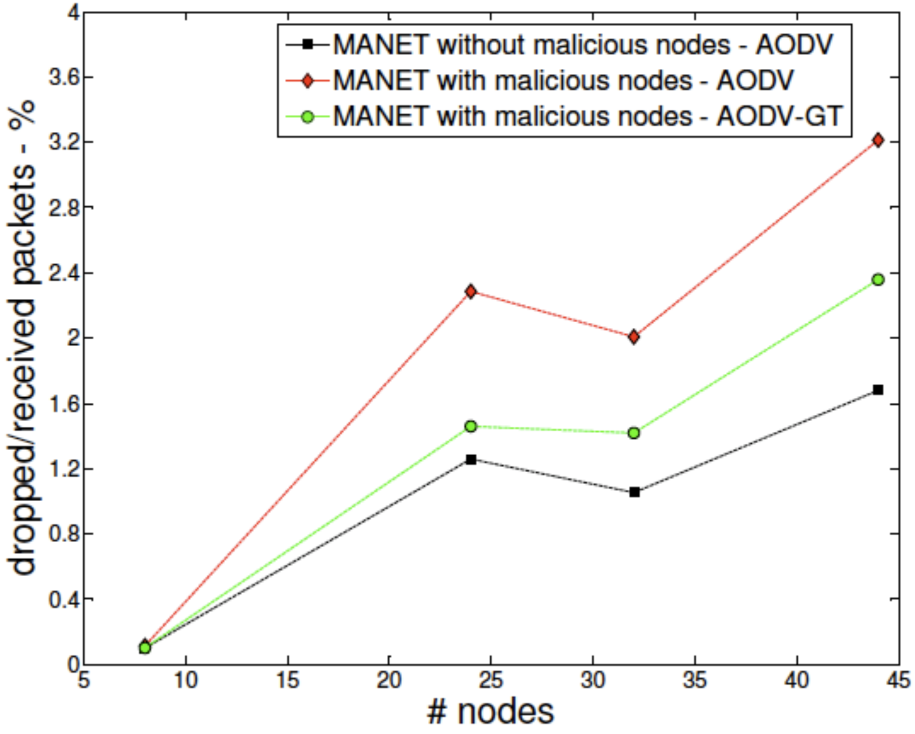
Simulation Results (2)

TCP traffic, 1000m x 1000m

v = 1 m/s



v = 5 m/s



Conclusions

- AODV-GT is an extension to AODV
- Requires the existence of HIDS
- Minimizes the consumption of HIDSs' resources
- Mitigates the harm of legitimate MANET nodes in presence of blackhole nodes

Thank you!

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