Resilient Consensus Through Trusted Nodes

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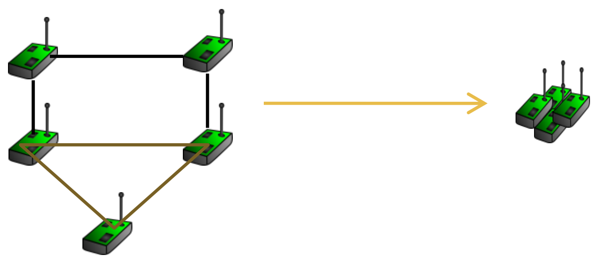
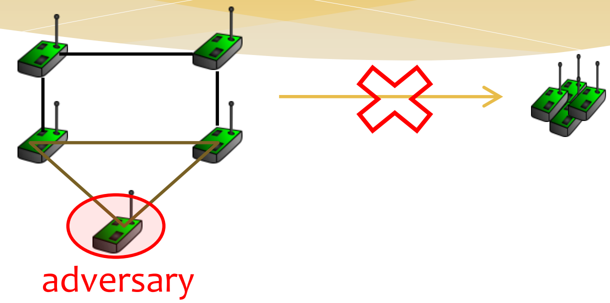
Motivation



Consensus: agents agree upon a common value
Applications: optimization, sensor networks, estimation, etc.



Resilient consensus: consensus in the presence of adversaries

Existing Resilient Consensus Protocols

- **Non-local information**
  e.g., node knows the overall network topology
- **High connectivity**
  e.g.,
  - ***(2F+1)*-connected**
  - **(r,s)-robust**
- **Conditions hard to verify**
  e.g., (r,s)-robustness
- **Dependence on parameter F (no. of possible attacks)**
  e.g., F-Total , F-local etc.

Can these issues be addressed?

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Motivation

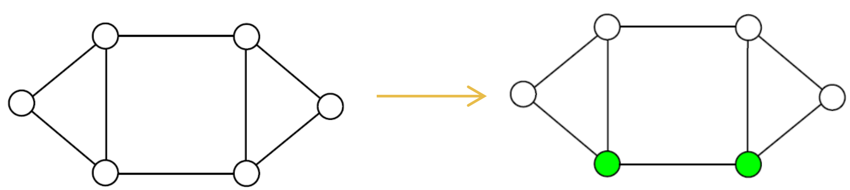
Resilient networks
(various approaches to resilience)

Connectivity of underlying graph

Nodes' capabilities **(security levels)**

some nodes are **more secured** against adversarial attacks

By **how much** can we improve the **resilience** of a network by adding **few trusted nodes**?



Trusted Nodes

- Highly secure.
- Cannot be compromised by attacks.

Resilient Consensus with Trusted Nodes

Design an update rule such that all normal nodes, a subset of which consists of **trusted nodes,** achieve consensus even in the presence of **any** number of adversaries.

i.e., design an update rule that achieves consensus.

Consensus:

- Agreement

$(\text{as } k \to \infty,\ x_i(k) \ = \ x_j(k))$

- Safety

$(\forall\ k,\ \ x_i(k) \in [x_{\min}(0) \qquad x_{\max}(0)])$

Trusted nodes:

For any no. of adversarial attacks, find ***necessary and sufficient*** conditions on the

- ❑ number
- ❑ location
- ❑ connectivity

of trusted nodes to achieve consensus.

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Resilient Consensus Protocol (RCP-T)

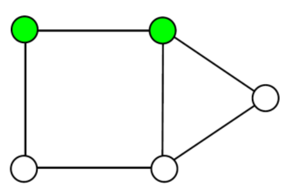
Under **RCP-T,** consensus is always achieved in the presence of ***arbitrary number of adversaries*** if and only if there exists a set of trusted nodes that form a **connected dominating set**.

Under RCP-T

- *Any* number of attacks can be handled
- *Sparse* networks can be made resilient

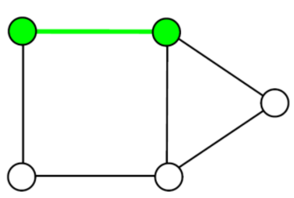
Dominating Set:

$$D \subseteq V, \quad \text{s.t.} \quad \bigcup_{v_i \in D} \mathcal{N}[v_i] = V$$



Connected Dominating Set:

Nodes in the dominating set induce a connected subgraph



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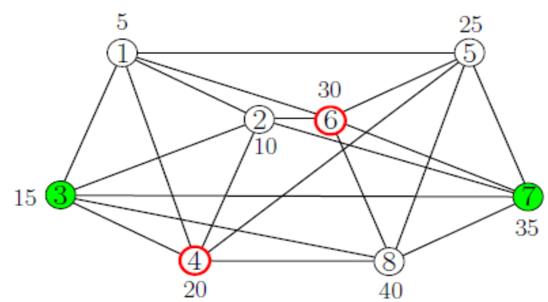
Example

Example:

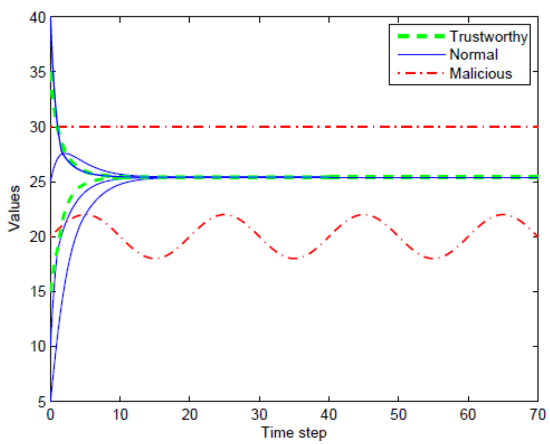
Attacked nodes $= \{4, 6\}$

Trusted nodes $= \{3, 7\}$

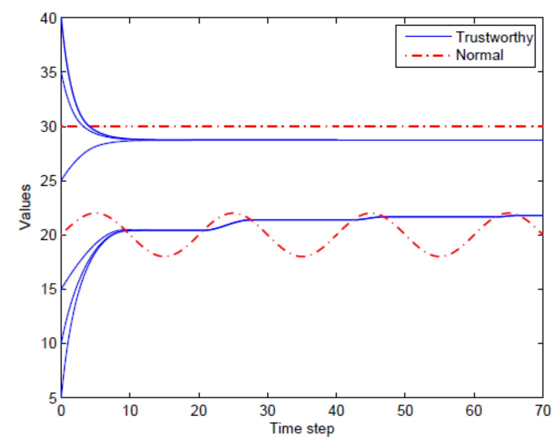


(2,2)-robust graph

RCP-T



W-MSR



- **RCP-T** achieves consensus even with two attacks
- **W-MSR** algorithm can handle a single attack, but not two adversaries

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Conclusions

Trusted nodes and Network Robustness

γ_c = Connected domination number

Resilience of networks if
$\text{No. of trusted nodes} < \gamma_c$

Sometimes adding as many as $(\gamma_c - 1)$ trusted nodes does not improve the resilience.

$\gamma_c \sim (r, s)-$ robust graphs

'Trusted nodes' ?

How can we generalize the notion of 'trusted nodes' for resilience in networks?

Graph domination

How can we utilize the concept of domination in graphs for resource distribution in networks.

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