Trust and Collaboration in Autonomic Networks

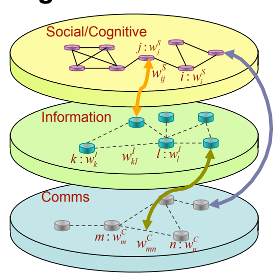
Tao Jiang and John S. Baras

Network Science

- A network is a collection of nodes, agents, …
  - that collaborate to accomplish actions, gains, …
  - that cannot be accomplished with out such collaboration
- Network science
  - The Internet and other communication networks
  - Social networks
  - Biological networks
- Fundamental knowledge is necessary to design large, complex networks in such a way that their behaviors can be predicted prior to building them. (From National Research Council report on Network Science -- The National Academies Press, 2005)

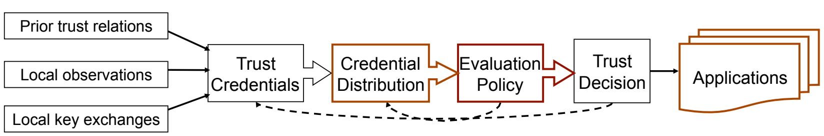
Case study: Trust Management

- Multiple Interacting Graphs (Directed graphs)
  - *Nodes*: agents, individuals, groups, organizations
  - *Links*: ties, relationships
  - **Weights on links** : value (strength, significance) of tie
  - **Weights on nodes** : importance of node (agent)
- **Value directed graphs with weighted nodes**
- **Real-life problems: Dynamic, time varying graphs, relations, weights**



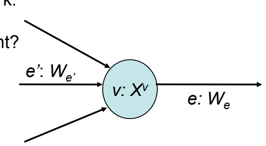
Organizational needs
Network architecture and operation

- Objective: use mathematical analysis to understand and predict the emergent behaviors of distributed trust management systems in autonomic networks.



Trust Credential Distribution

- No centralized trusted party; trust credentials are scattered in the network.
  - Where and how to find all needed credentials?
  - Where and how to store credentials such that searching is efficient?
- Network Coding Based Scheme
  - Extremely simple to implement
  - Only local information exchange
  - Easy for discovering new credentials
  - Efficient distribution



$$W_e = A_e\vec{X}^v + B_e\vec{W}^v = C_e\vec{X}$$

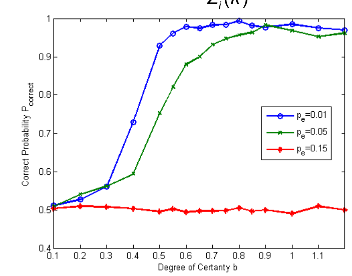
Trust Evaluation Policy

- The trustworthiness of an agent is based on other peers' opinion
  - The most straightforward scheme is to ask neighbors to "vote" for it.
  - **Iterated stochastic voting:** $\Pr[s_i(k+1) \mid s_j(k), j \in \hat{N}_i] = \dfrac{\prod_{j \in N_i} \Pr[d_{ij}, d_{ji} \mid s_i(k+1), s_j(k)] \cdot \Pr[s_i(k+1)]}{Z_i(k)}$
  - **Convergence:** unique stationary distribution.

Phase transitions in two parameters:

- Degree of certainty b
- Probability of error p_e

Theoretical analysis: results in the Ising model and the spin glass model, where $d_{ij} = J_{ij}$; replica method.



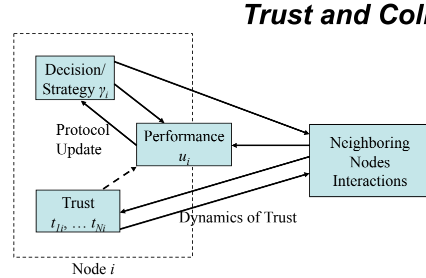
Case study: Collaboration

- The nodes **gain** from collaborating
- But collaboration has **costs** (e.g. communications)
- **Fundamental trade-off**: gain from collaboration vs cost of collaboration

Constraint Coalitional Game

- **Network formation game**:
  - Payoff of node i from the network G is defined as $v_i(G) = \text{gain} - \text{cost}$
  - Iterated process
    - Node pair ij is selected with probability p_{ij}
    - If link ij is already in the network, the decision is whether to sever it, and otherwise the decision is whether to activate the link

Trust and Collaboration



Two linked dynamics:

Trust propagation and game evolution

$$\gamma_i(k+1) = f^i(u_i(k), \gamma_i(k), \gamma_j(k), t_{ji}(k))$$

$$t_{ih}(k) = g^i(\gamma_h(k), t_{ih}(k-1), t_{ij}(k), v_{ji}^h(k)), \quad \forall h \in N$$

$$u_i(k) = h^i(\gamma_i(k), \gamma_j(k))$$

Objective:

- to find what form or policy can induce all (or most) nodes to collaborate: **maximize** the coalition.

Two solutions:

- **Negotiation**: Players with positive gain can negotiate with their neighbors by sacrificing certain gain.
- **Trust**: By introducing a trust mechanism, all nodes are induced to collaborate without any negotiation.