

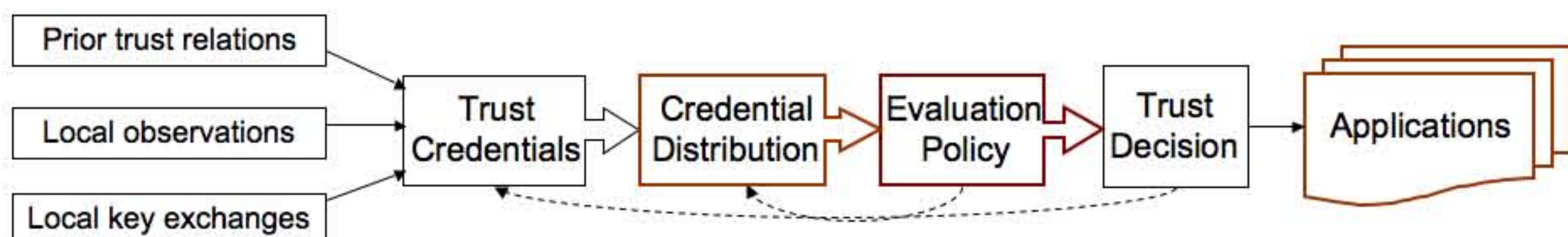
## Motivation

- Communication networks have been involved to be so complex that people, who created them, cannot control them.
  - **Future vision:** to understand and control such complexity.
  - Network science
    - The Internet and other communication networks
    - Social networks
    - Biological networks
- ➔ **They are autonomic.**

## Trust in Communication Networks

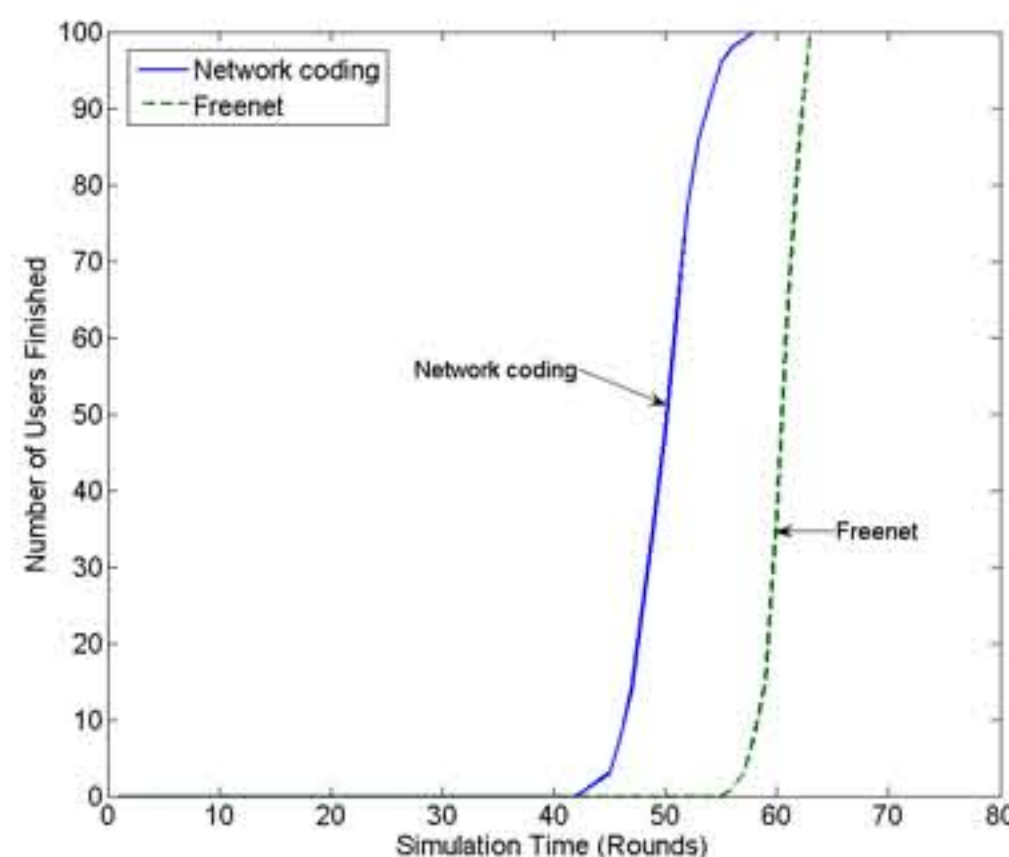
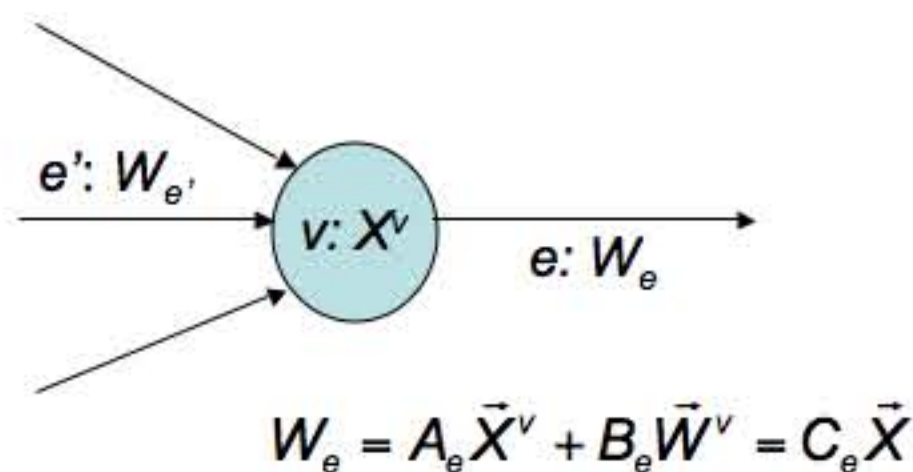
Traditional networks	Autonomic networks
Internet, cellular networks	MANETs, P2P
Centralized trusted authority	No trusted centralized authority Uncertainty and incompleteness Local information exchange Distributed computation

- **Objective:** use **mathematical analysis** to understand and predict the **emergent behaviors** of trust management systems in autonomic networks.
- Trust Management System in Autonomic Networks:



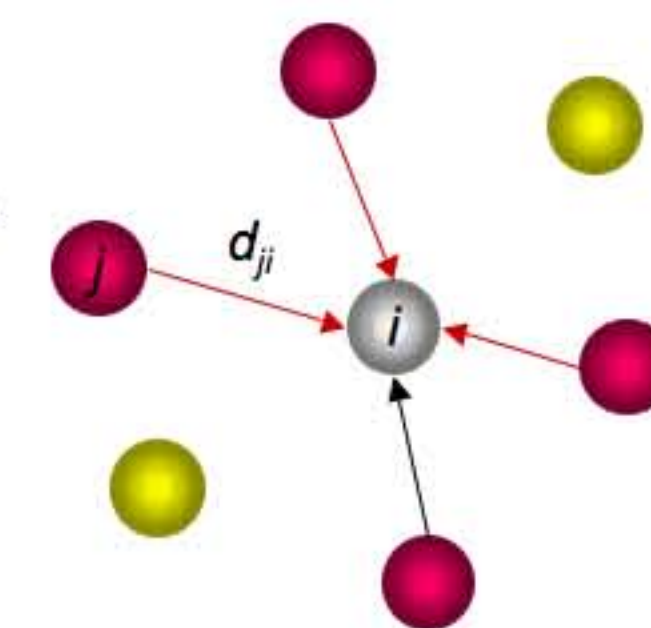
## Trust Credential Distribution

- No centralized trusted party; trust credentials are scattered in the network.
- **Problems:**
  - Where and how to find all needed credentials?
  - Where and how to store credentials such that searching is efficient?
- P2P file sharing:
  - The problem of trust credential distribution shares many characteristics of P2P file sharing systems (Freenet).
  - Network coding based file sharing has been shown to be efficient and based on local information only.
- **Network Coding Based Scheme**
  - Extremely simple to implement
  - Only local information exchange
  - Easy for discovering new credentials
  - Small storage requirement
  - Efficient distribution



## 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.
  - **Voters:** neighbors with **positive** trust value are qualified as legitimate voters.
  - General voting rule:  $s_i = f(d_{ji}, s_j, \forall j \in N_i, s_j > 0)$ .



- **Stochastic voting:**

$$\Pr[s_i(k+1) | s_j(k), j \in \hat{N}_i] = \frac{\prod_{j \in \hat{N}_i} \Pr[d_{ji}, d_{ij} | s_i(k+1), s_j(k)] \cdot \Pr[s_i(k+1)]}{Z_i(k)}$$

- **Convergence:**

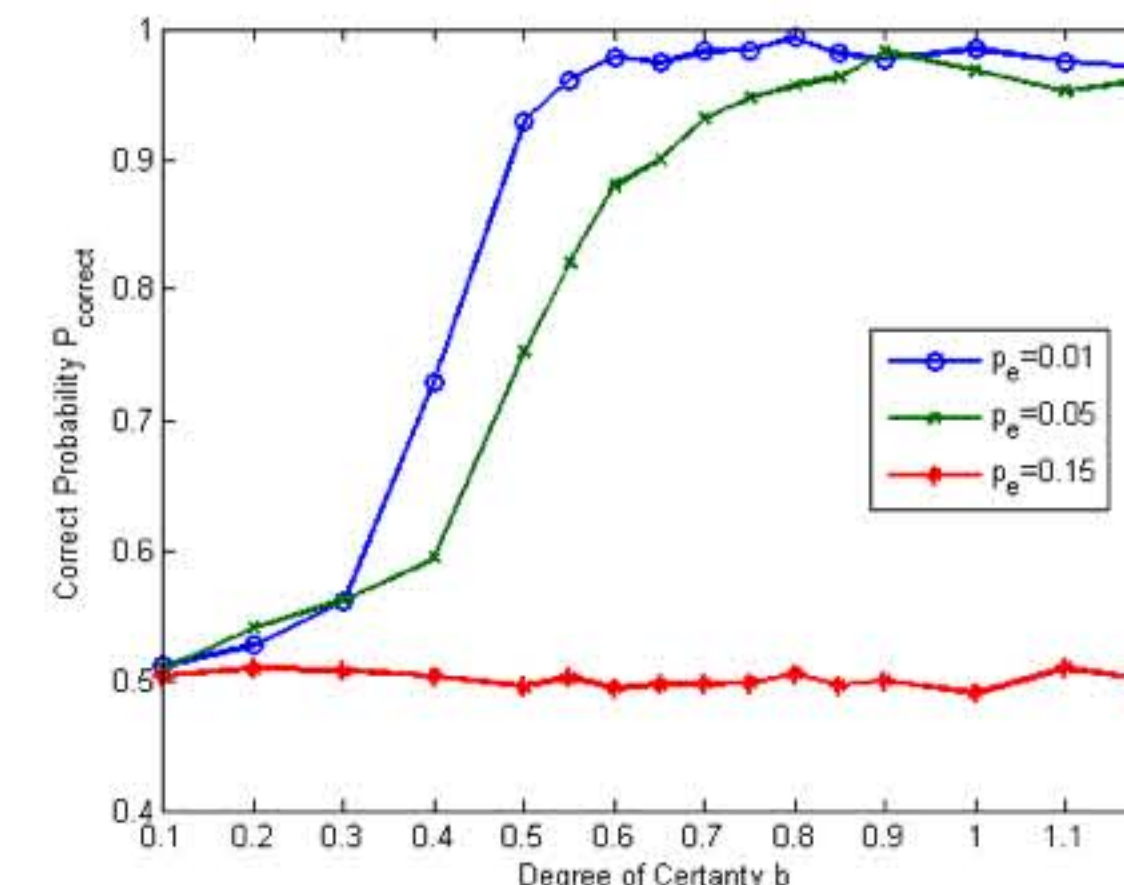
- The update rule iterates over time. We are interested in the steady state.
- The stochastic voting can be interpreted as a Markov chain. Under trivial conditions, it can be shown that the update rule converges to a unique stationary distribution.

- Criterion: probability of correct estimation.

Phase transitions in two parameters:

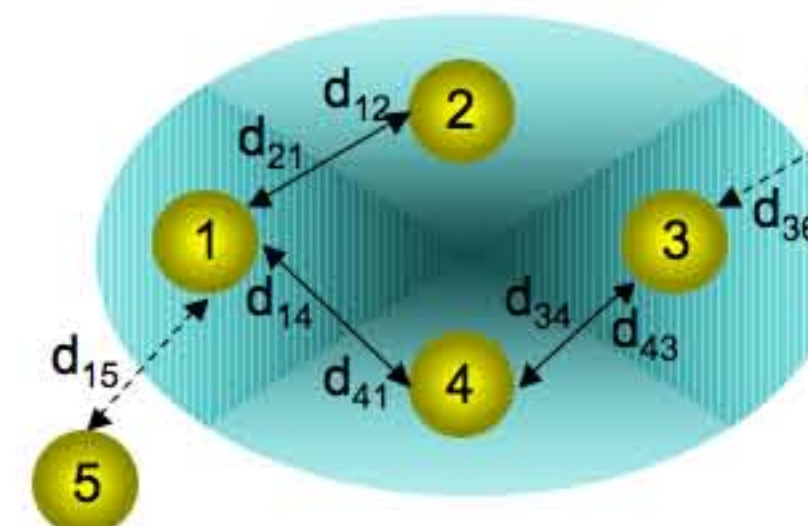
- Degree of certainty  $b$
- Probability of error  $p_e$

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



## Trust and Cooperation

- The evaluation rule can be interpreted as **dynamic (repeated) games**:
  - $d_{ij}$  can be interpreted as the worth of player  $j$  to player  $i$ .
  - The game is interpreted as a **cooperative game**, where nodes who collaborate with neighbors form a **coalition**.
  - The characteristic function of a coalition  $S$  is defined as  $v(S) = \sum_{i \in S} \pi_i = \sum_{i, j \in S} d_{ij} - \sum_{i \in S, j \notin S} d_{ij}$ .



Subset  $S = \{1, 2, 3, 4\}$   
 $v(S) = d_{12} + d_{21} + d_{14} + d_{41} + d_{43} + d_{34} - d_{36} - d_{15}$

Objective:

- to find what form or policy for  $d_{ij}$  can induce all (or most) nodes to cooperate: **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.

