Modeling the Spread of Actionable Information in Social Networks

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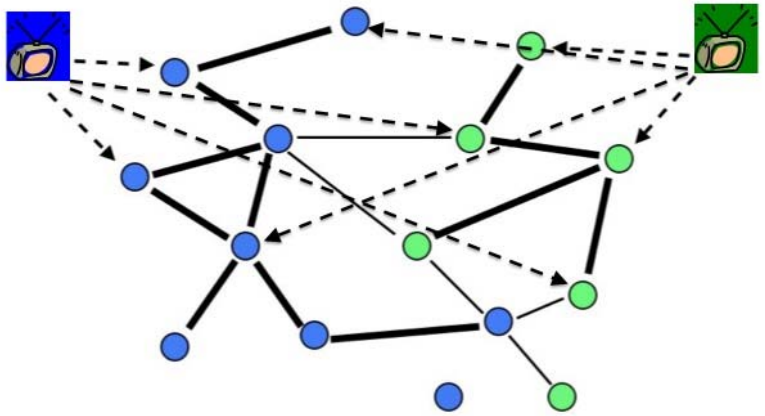
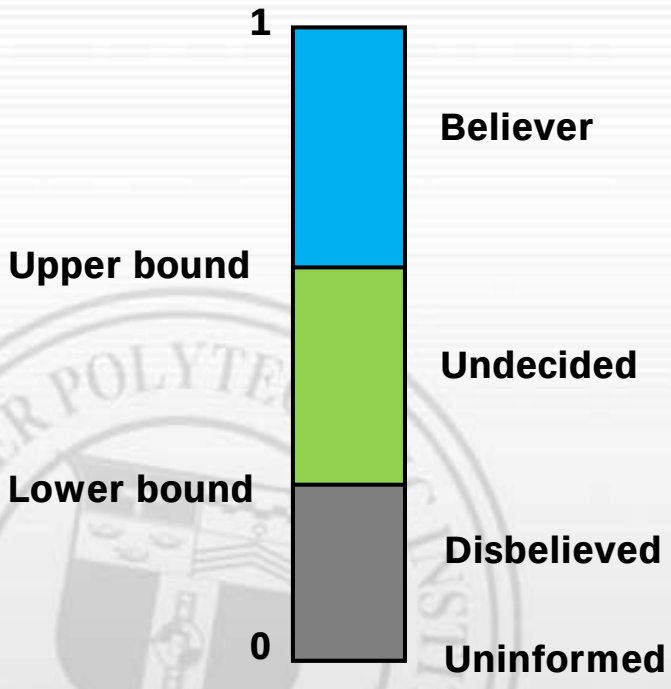
Diffusion Model of Actionable Information

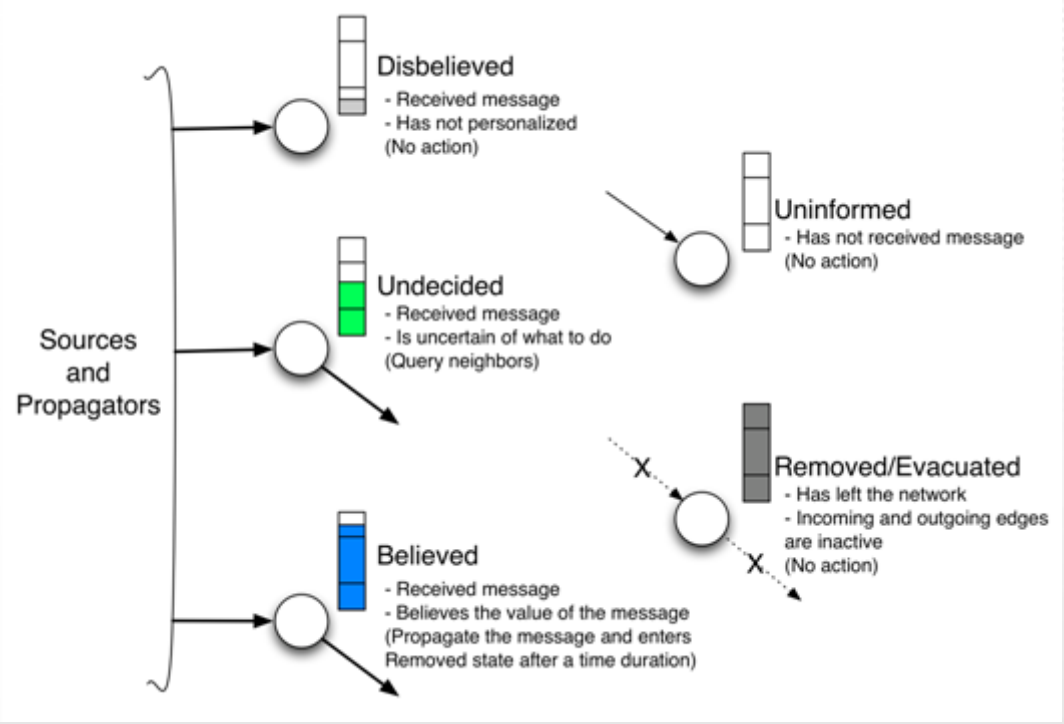
- Agent-based model
- Trust: The information value of the message is a function of the social relationship between the sender and the receiver
- General model of diffusion in dynamic networks



Nodes Process and Act on the Information

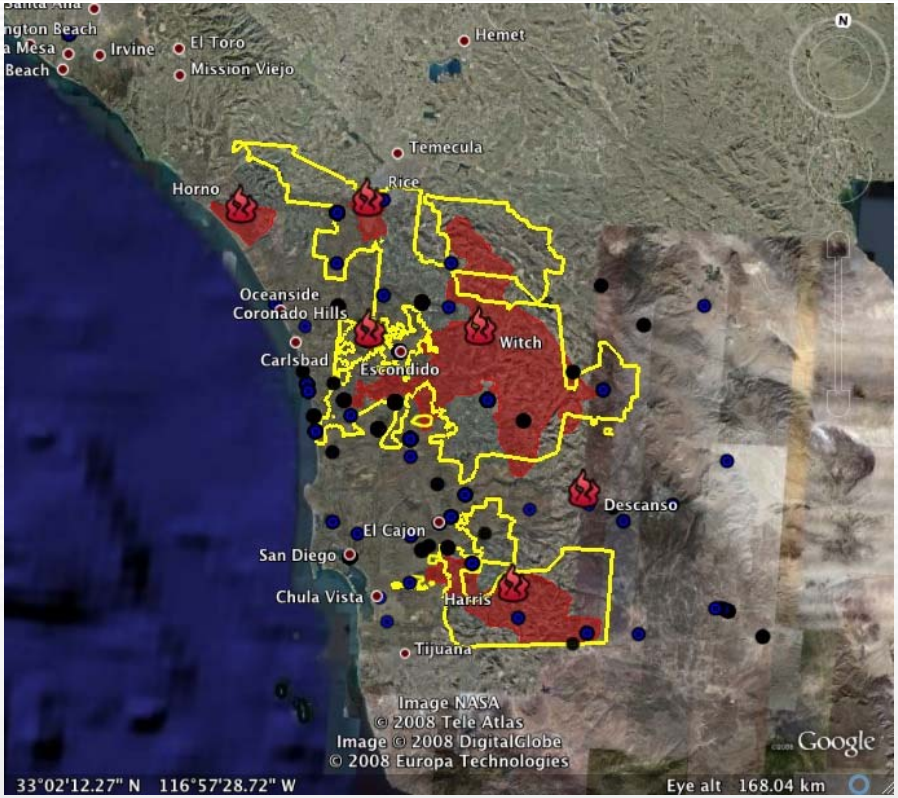
- Each node *k* has a $Message\_set_k = \{S_1,V_1\}, \ldots \{S_m,V_m\}$
- Fused value of the Action messages: $Message\_fused_k$





San Diego Firestorms 2007

- Consisted of separate fires within San Diego County
  - Oct 21 (Start of first fire)
  - Nov 9 (Last fire contained)
- Burned a total of over 368,340 acres, destroyed an estimated 1,600 homes
- Used Reverse 911 telephone-based mass notification systems to assist in evacuating more than 515,000 residents



San Diego map showing the estimated fire perimeters (in red) and evacuation areas (in yellow) for October 24th on Google Earth.

Large-scale Experimentation

- Utilize demographic and event data to construct models to investigate questions of interest regarding diffusion in large-scale networks

- Procedure
  - Construct a social network of households
  - Script the events of San Diego Firestorms
  - Configure model parameters using data sources
  - Validate the model configurations by obtaining results close to the actual reported number of evacuated households
  - Simulate the spread of evacuation warnings on the constructed networks

Social Network of Households

- Demographically based network with two groups
  - ~29% Hispanic
  - ~71% Non-Hispanic households
- Network size of 1,000,000 households
  - Edges between the households are defined using probabilities based on their geographic distance and their group

Source: http://www.sandag.org

San Diego County After Action Report

- Scripted the notifications between Sun Oct 21 and Wed Oct 24
  - Time step 0: Sun Oct 21 8:00 am
  - First source activated on Sun Oct 21 10:30 am (time step 2)
  - Last source activated on Tues Oct 23 at 8:15 pm (time step 60)
- Assigned information value of the messages
  - Mandatory evacuation order or an advisory notification
- Calibrated 32 sources
  - Each source node is an instance of an information source
  - Each source delivers warning messages to a randomly selected number of household nodes in the specified region

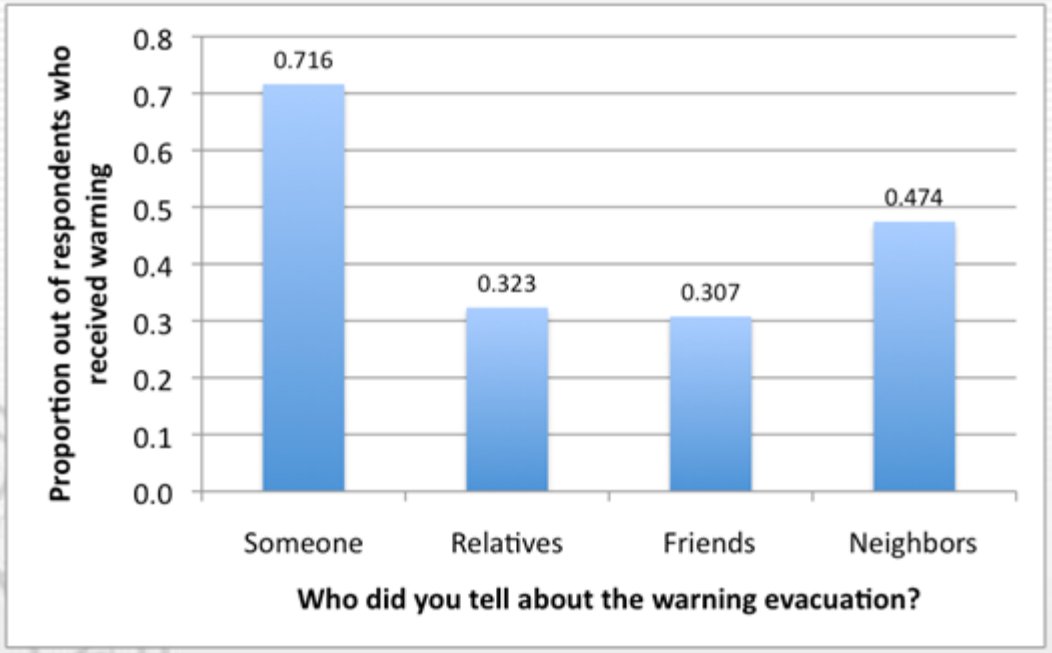
Survey Data from Oak Ridge National Lab

- Out of 1210 responses, 761 reported that they received a warning
  - 590 received a warning from Reverse 911
  - 510 received their first warning from Reverse 911

- Proportion of total survey respondents that contacted someone about the evacuation warning, approx. 41%

- 707 respondents provided information on time to evacuation
  - 458 (64.78%) reported taking up to 1 hour
  - 129 (18.25%) reported taking up to 2 hours
  - 82.75% left their residence within 2 hours after making their decision to evacuate

Spreading Warnings Through Informal Network



Variables Related To Evacuation Behavior

Table 4.2: Regression coefficients for the dependent variable: whether the respondent evacuated.

	Unstandardized Coeff.		Standardized Coeff.	t	Sig.
	B	Std. Error	Beta		
(Constant)	.378	.020		18.643	.000
receivedReverse911	.199	.034	.202	5.891	.000
receivedVisual	.164	.037	.167	4.415	.000
receivedFormal	.123	.037	.092	3.300	.001
receivedMedia	-.052	.033	-.051	-1.589	.112
receivedInformal	.173	.035	.135	4.878	.000

Warning Confirmation Is Important

Table 4.4: Evacuation statistics by the number of warning sources that the respondents reported receiving a warning from

		Number of Sources				
Evacuated	No warning	One	Two	Three	Four	Five
No	285	22	59	114	15	5
Yes	164	22	154	294	76	5
Total	449	44	213	408	91	5

Table 4.9: Number of respondents who evacuated for people who received Reverse 911 as the first warning followed by at least a warning from the listed sources.

Source	Number Evacuated	Total	Percent Evacuated
None	11	23	47.83%
Formal	86	107	80.37%
Media	205	302	67.88%
Informal	75	85	88.24%
Visual	320	426	75.12%
Total	370	510	72.55%

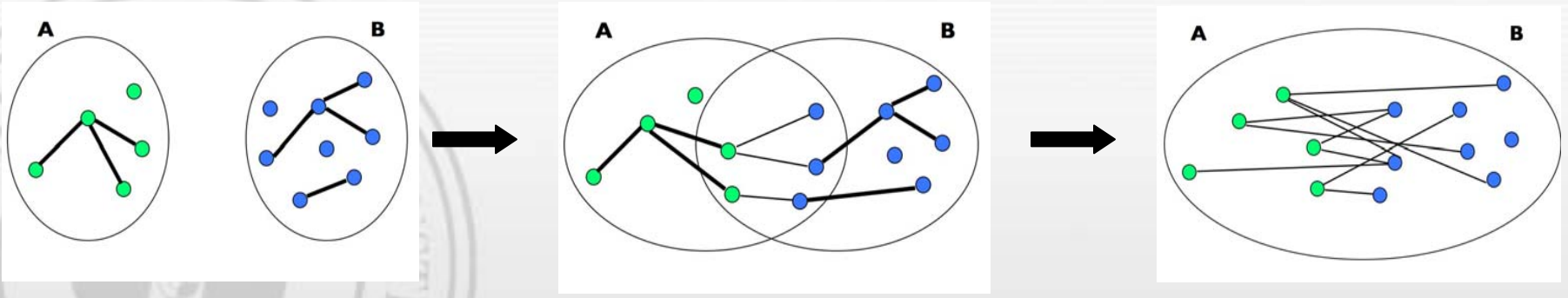
Large-scale Simulation Using Wildfire Scenario

Q1: How does the distribution of trust impact information diffusion?

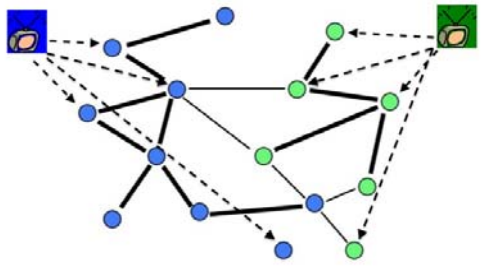
- Social groups as modeled using trust

Q2: How does the strength of ties and structure play a role in the diffusion process?

- Trust between pairs of nodes (strong tie and weak tie)
- Proportion of edges connecting nodes from different groups



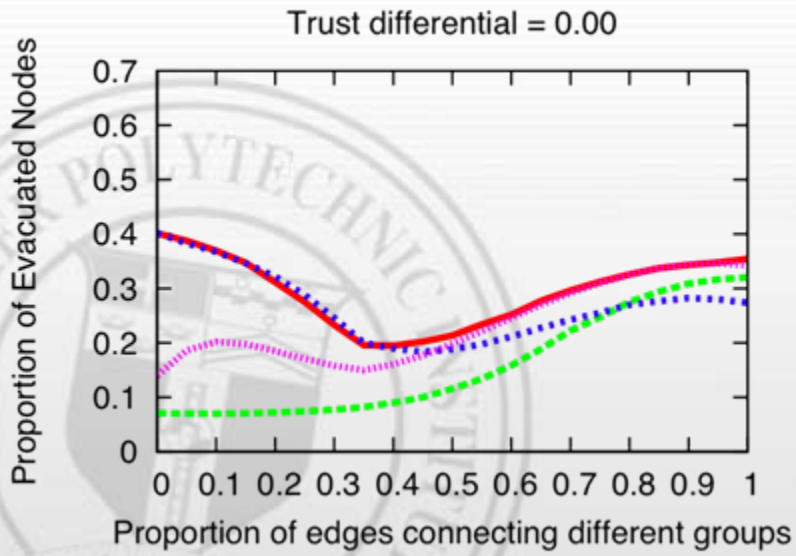
Importance of Bridging Information



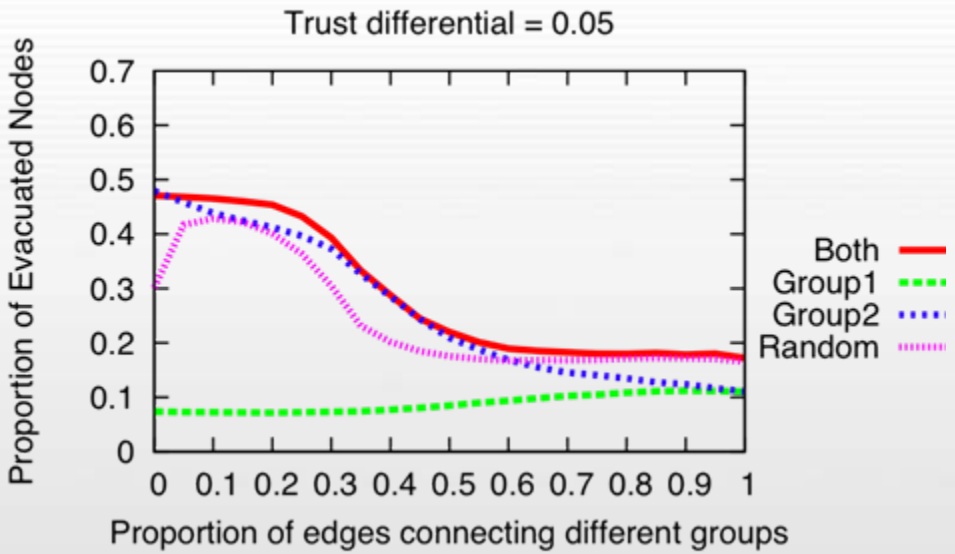
Compare the cases where informationreaches both groups

- reaches only one group (Majority)
- reaches only one group (Minority)
- information randomly selects one group for each broadcast

Left: Equal trust values

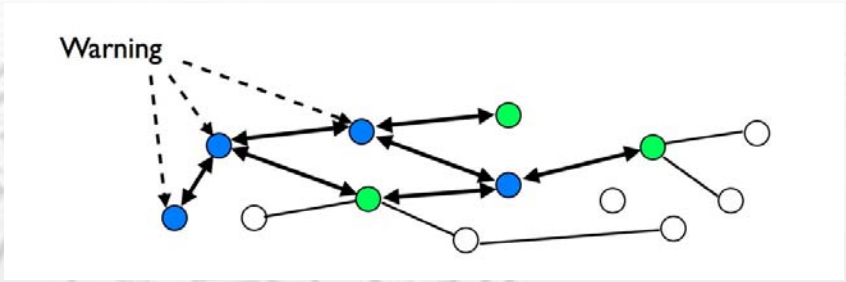


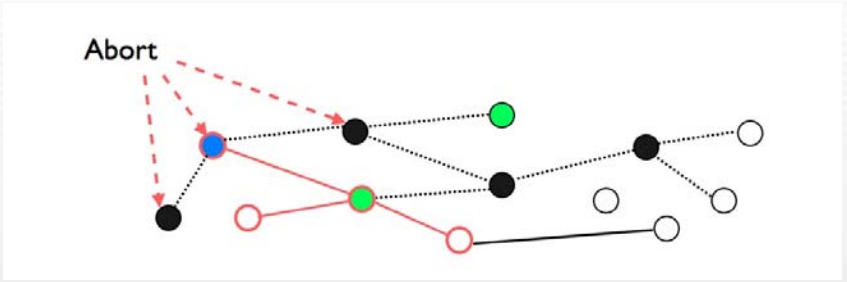
Right: Trust values based on groups



Diffusion Model with Abort Information

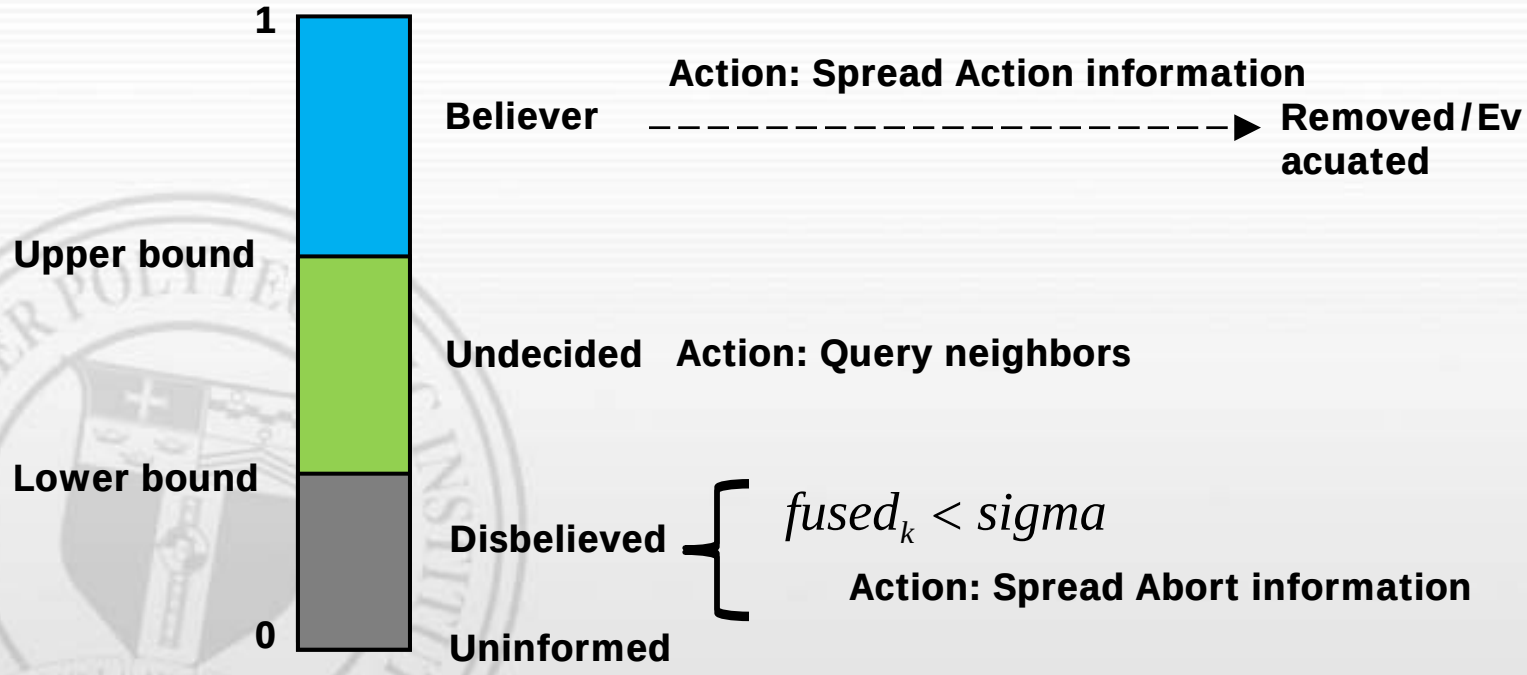
- Abort message will be broadcasted at a later time after the Action message has been introduced in the network.
- The Abort message will spread on the network that evolved from the diffusion of the earlier Action message.





Nodes Combine Action and Abort Information

- Each node *k* has a $Message\_set_k$ and an $Abort\_set_k$
- Fused value of the Action messages: $Message\_fused_k$
- Fused value of the Abort messages: $Abort\_fused_k$
- Compute $fused_k$ as a function of $Message\_fused_k$ and an $Abort\_fused_k$



Empirical Study of Action-Abort Model

Q1: What are strategies for spreading and immunizing information?

- Methods for selecting seeds to broadcast Abort information (e.g. Retraction, Random, Degree)
- Time between broadcast of Action messages and Abort messages

Q2: How does the distribution of trust affect the spread of Abort information?

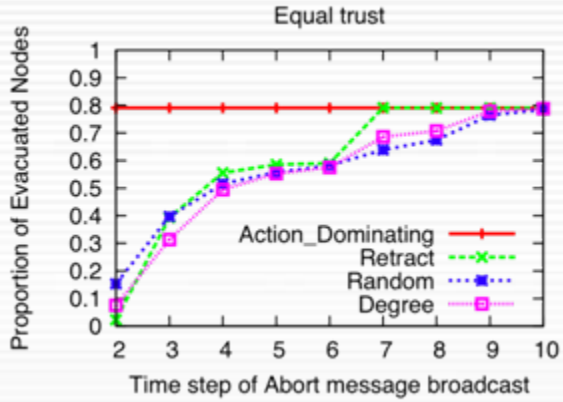
- Compare equal trust values with trust values based on groups

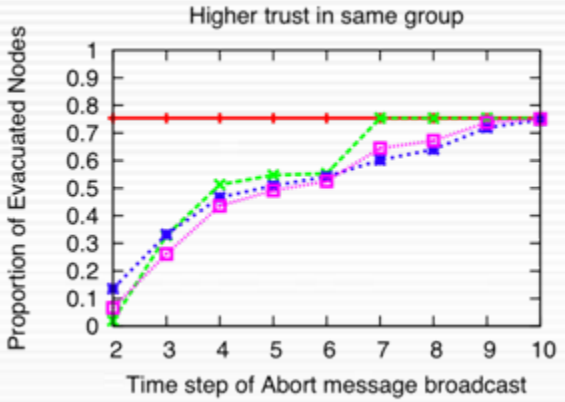
Effectiveness of Information Retraction

Simulation results for a Group model network with 100,000 nodes

Setting 1

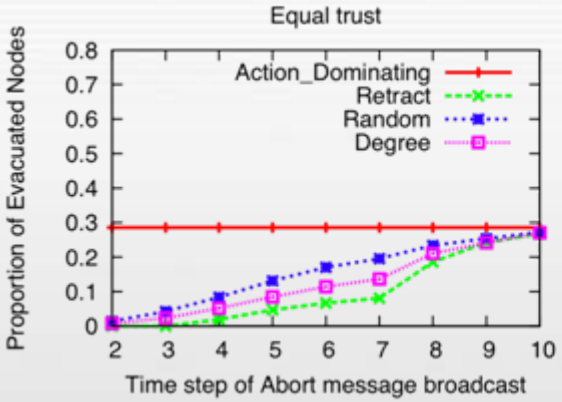
Seed nodes enter Believed state

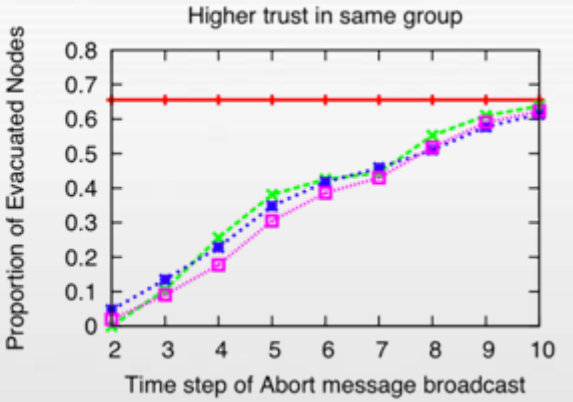




Setting 2

Seed nodes enter Undecided state





Conclusions

- Diffusion of actionable information in dynamic large-scale networks
  - Dynamics result from the information flow
  - Model is configurable and can be extended to fit various context
- Large-scale experimentation, Wildfire Scenario
  - Social groups as modeled using trust promotes the spread of information
  - Existence of strong and weak ties plays an important role in the diffusion process
- Diffusion model with Abort information
  - Retraction strategy is most effective if abort is triggered soon after the initial message
  - Retraction may be a possible strategy in a network with homogeneous trust, but is not useful when there are trust differentials and groups

Future Work

- Model extensions
  - Mechanisms for information fusion
  - Timing in which messages are received
  - Information confirmation
- Study strategies for spreading and impeding spread of information under given network characteristics
  - Dynamic strategies for selecting seeds to broadcast information which considers network dynamics and changes due to information flow
- Investigate trade off between effective spread of actionable information and the ability to retract or counter the actionable information

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Thank you!

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