Broadcasting in DTN as an Epidemic Dynamics

A. Maiti[1], F. Peruani[2], R. R. Choudhury[3], N. Ganguly[1]
1-Dept. of CSE, IIT Kharagpur, India, email- {abyaym,niloy}@cse.iitkgp.ernet.in
2-CEA/SPEC and ISC-PIF, France, email- peruani@pks.mpg.de
3-Dept. of ECE and Dept. of CS, Duke University, USA, email- romit@ee.duke.edu

BACKGROUND

❖ Message broadcasting in DTN and epidemic spreading are analogous.

❖ Epidemic spreading models like **SIRS**, SIR, SIS.

❖ Advent of Directional Antenna (DA).

PROBLEMS ADDRESSED

❖ Modeling broadcasting with mean field approach.

❖ Estimation of broadcasting time in DTN.

❖ Comparative study of omni-directionl antenna (OA) and DA .

AGENT BASED MODEL

❖ Agents are self-propelled and move at constant speed while changing its direction at Poissonian distributed times.

❖ DA changes its orientation at each time with a fixed probability (p_{rot}).

❖ Agents can be in one of three possible states:

- ***Susceptible*** - Active without the message
- ***Infected*** - Received and broadcasting the message for a given time (τ_I)
- ***Recovered*** - Idle mode for fixed amount of time (τ_R) after broadcasting

❖ States are changed periodically in S-I-R-S cyclic order (**SIRS** model)

MOBILITY AND SIGNAL TRANSMISSION

❖ The motion of the i^{th} agent :

$$\dot{\mathrm{x}}_i(t) = v\left(\cos(\alpha_i)\breve{x} + \sin(\alpha_i)\breve{y}\right)$$
$$\theta_i(t) = F_\theta(t)$$

α_i - direction of motion
v - velocity
$\theta_i(t)$ - antenna orientation

❖ Power received by agent i from transmitting agent j (**Friis eq.**)

$$P_r(\mathrm{x}_i, \theta_i, \mathrm{x}_j, \theta_j) = \frac{\lambda^2 P_t G_T(\theta_j, \mathrm{x}_j, \mathrm{x}_i) G_R(\theta_i, \mathrm{x}_i, \mathrm{x}_j)}{(4\pi)^2 \left|\mathrm{x}_i - \mathrm{x}_j\right|^2}$$

λ - signal frequency
G_T , G_R - gain of the agents in the direction to each other

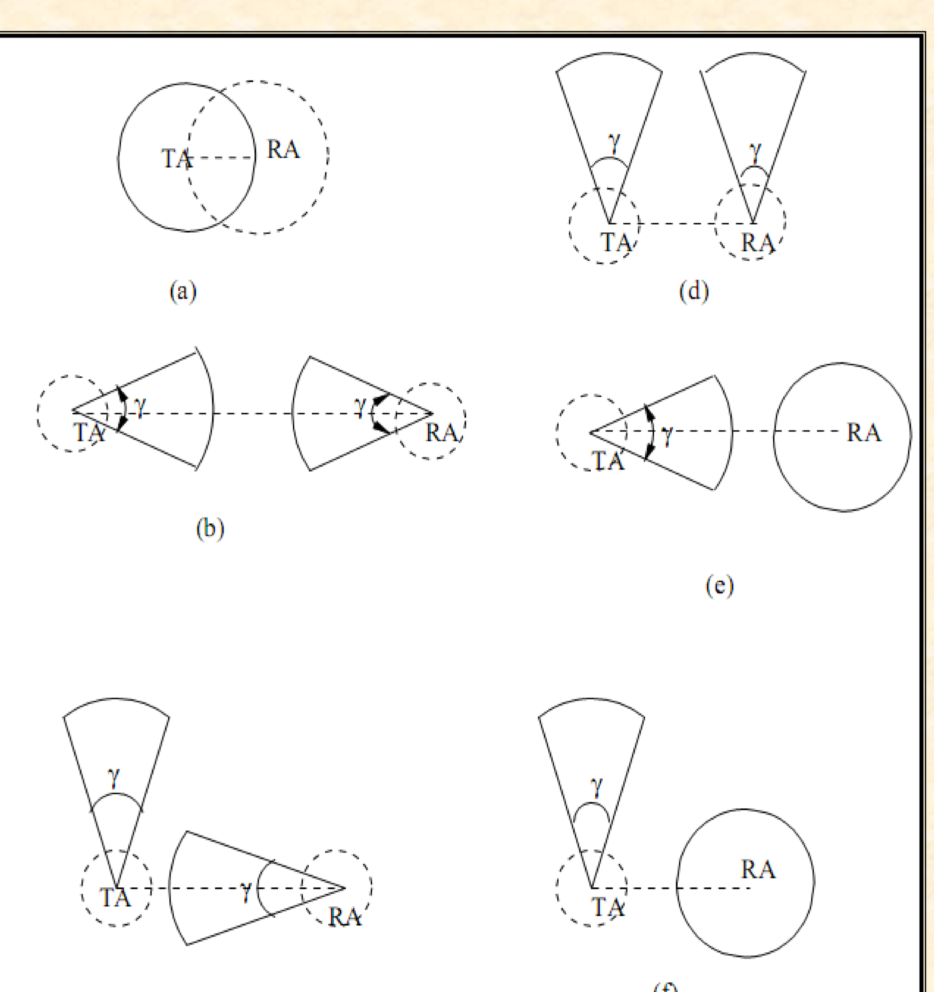
❖ Agent i receive the message from j if P_r crosses a certain threshold.

SYSTEM WITH DA & OA

❖ System can have a mixture of OA and DA agents.

❖ OA and DA both have the same power.

Six possible relative orientations of antennas.
γ - antenna beam width
TA - transmitter
RA – receiver



MEAN FIELD SOLUTION

❖ Systems with 100% OA can be represented by mean-field approach:

$$\dot{S} = \frac{R}{\tau_R} - (\rho\psi)IS$$
$$\dot{I} = (\rho\psi)IS - \frac{I}{\tau_I}$$
$$\dot{R} = \frac{I}{\tau_I} - \frac{R}{\tau_R}$$

N - total number of agents
N_S, N_I , N_R - number of S, I and R respectively
$S = N_S/N$
$I = N_I/N$
$R = N_R/N$
ρ - agent density
ψ - new area an agent explores per time unit

❖ Fraction of informed agents at time t :

$$Y(t) = \left(\frac{1}{N} - 1\right)\exp\left[-(\psi\rho)\int_0^t dt' I(t')\right] + 1$$

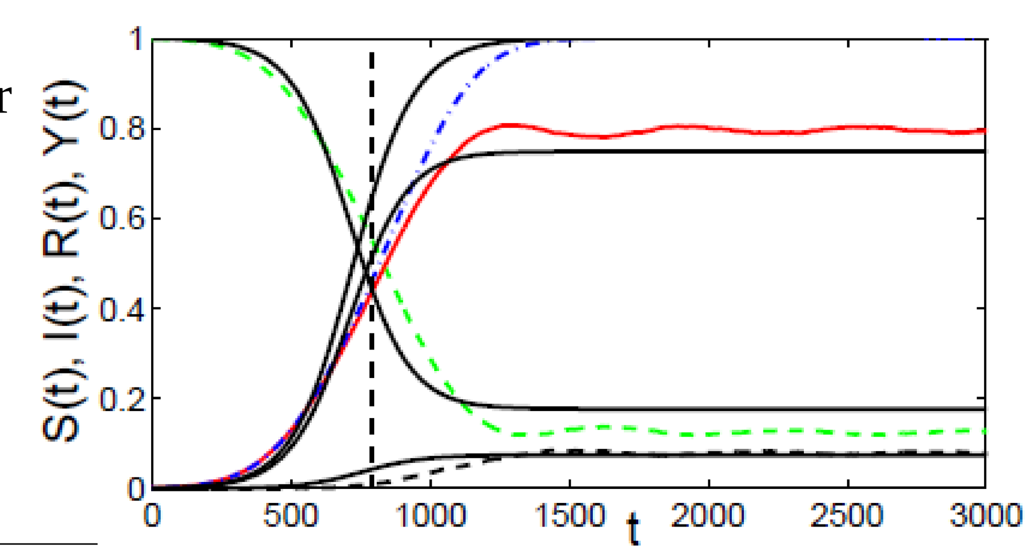
At $t = 0$, $N_I = 1$, $N_S = N - 1$, $N_R = 0$

$Y(t) = 1$ is possible at infinity

$Y(t)$ experiences a crossover when:

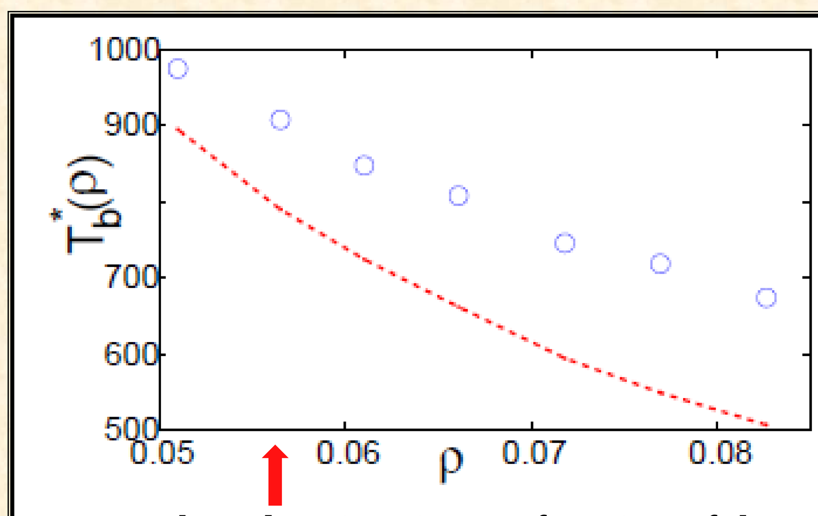
$$\int_0^{T_b^*} dt' I(t') = \frac{1}{\psi\rho}$$

T_b^* is defined as broadcasting time

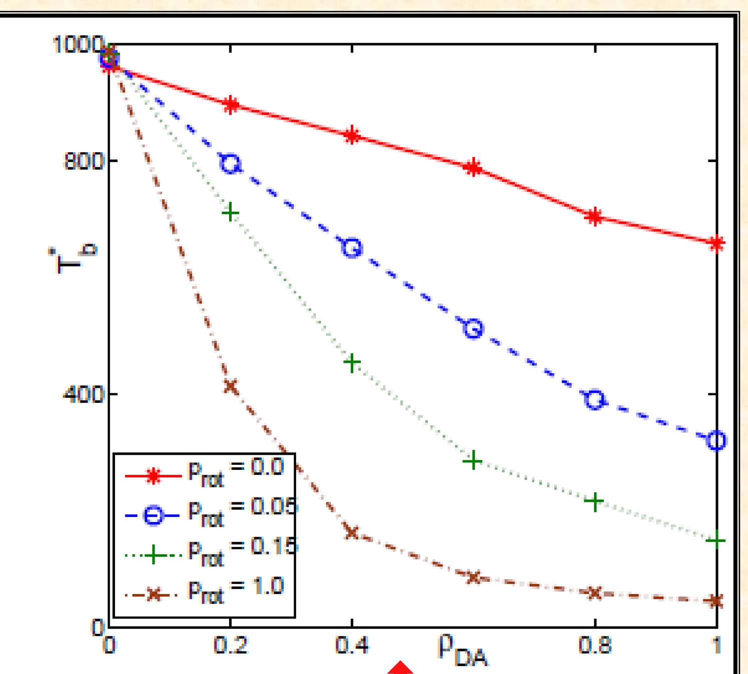


Time evolution of *S (green dashed), I (red solid)* , *R (black dashed),* and *Y (blue dash-dotted) for a system with N = 1000 agents with OA at a* density of *0.06. Black solid curves correspond to the mean-field approach.* The vertical black dashed line corresponds to the crossover.

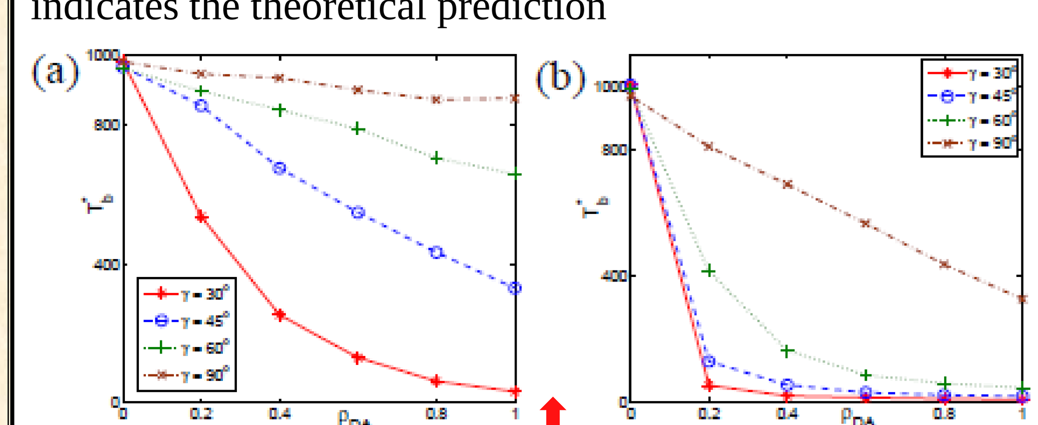
SIMULATION RESULTS



Average broadcasting time as function of the agent density with 100% OA. *N = 1000* . Circle corresponds to simulations, red dashed curve indicates the theoretical prediction

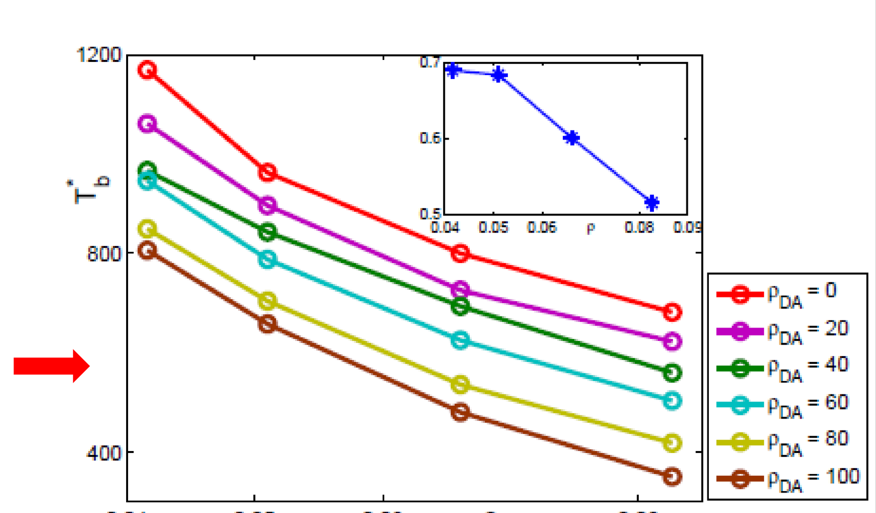


Average broadcasting time vs. DA fraction ρ_{DA} for various rotation probability p_{rot}, agent density ρ= 0.05, beam width γ = 60.



Average broadcasting time vs. ρ_{DA} for various values of antenna beam width γ with rotation probability (a) p_{rot} = 0 and (b) p_{rot} = 1 for an agent density ρ = 0.05.

Average broadcasting time vs. agent density for various values of ρ_{DA} , for γ = 60, p_{rot} = 0. (Inset) - Ratio of average broadcast time of system with ρ_{DA} = 100 and ρ_{DA} = 0 for different agent *density.*



CONCLUSIONS

❖ DA agents always perform better than the OA agents.

❖ DA agents with smaller γ are more efficient than those with larger γ.

❖ Rotation of the antenna has a definite positive effect on broadcasting.

❖ More research is needed to explore the effects of DA in DTN.

BIBLIOGRAPHY

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