Stigmergy-based Routing for Delay-Tolerant Content Centric Networks

Patrick Sénac
Anh Dung Nguyen
Michel Diaz
LAAS-CNRS and ISAE

Outline

1. Problem Statement
2. STIR Routing Protocol in a Nutshell
3. STEPS Mobility Model in a NutShell
4. Simulation Results
5. Conclusion and Perspectives

1. Problem Statement

The End of End to End

- Densification of the cyberspace: Billions of information sources/destinations and services
- High dynamicity of the cyberspace: increasing rate of cyber-object creation/destruction
- End system address is meaningless
- The information becomes the fixed point for communication purposes
  - The network as a service and content base
- Users interested by information whatever the (trusted) sources are.

Content Centric Network

- Publish/Subscribe paradigm
  - Cyber-Objects as content/service providers (temperature/ presence sensor, actuators….) publish their services.
  - Users, objects subscribe to these services:
- The cyberspace structured as a semantic space of services
- Several content/service providers can deliver the same content/service (anycast/castany)
- Any trusted system can take the role of a proxy for service/content delivery
  - Content limitation period (data scheduling issues)

When CCN Meets DTN

- DTN as a shell Internet:
  - Unavoidable component of the ambiant Internet
    - « Free » extension of the communication infrastructure
    - Use the increasing ressource capacity of end systems
    - Alleviate the core load
  - Store move and forward paradigm
- Combining pervasive ambiant networks with pervasive ambiant services leads to DTCCN

Main Challenges for DTCCN

- Efficient content centric network
  - Efficient routing: Minimization of delay, resource use (memory, bandwidth, energy)
    - Location based routing, bio-inspired routing….
  - Efficient transport: Continuous/real time delivery
    - Adapted error, congestion and flow control mechanisms with limited or no feedback from receivers
- Scalability
  - Resist to huge space of services
  - Resist to huge number of service providers/users with limited resources
  - Resist to diversity of topologies
    - From fixed and fully connected topologies (intelligent building)
    - To dynamic and partially connected topologies (disaster field): Delay Tolerant CCN
- Modeling and simulation of DTCCN
  - Mobility models

Content routing in DTCCN

- Efficient content delivery (service activation) between content (service) providers and content/ service users.
  - Routing by content (semantic routing) instead of routing by address
- Basic premise: In real life communities spatio-temporal correlation between mobile agents.
- Idea: Define a routing protocol that leverages the stigmergy between agents
  - Bio-inspired or physical inspired solutions to establish gradient fields between service providers and users.

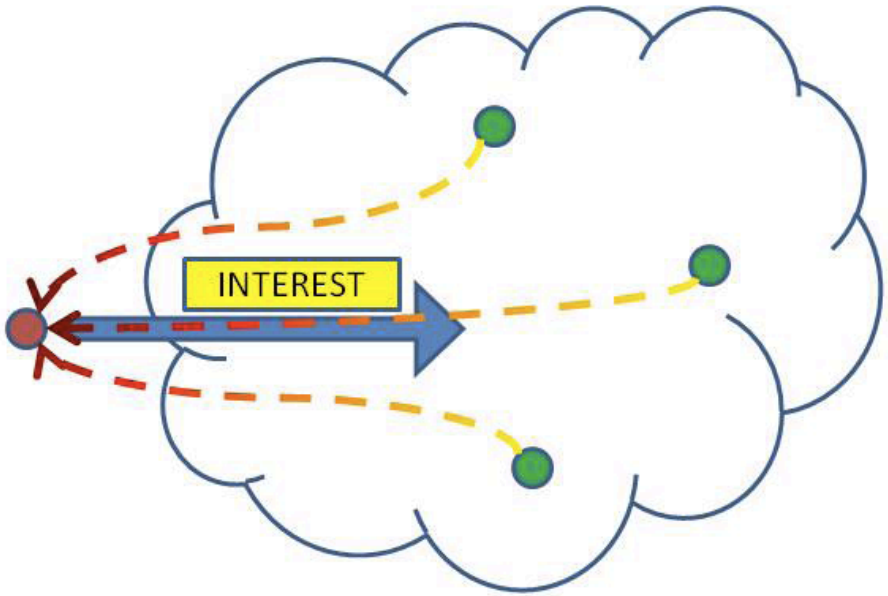
Use Case

- Smart building as a set of service/content providers (sensors, actuators…)
- A user enters the smart building
  - A user profile specifies the services relevant to the user
  - An ambiant service delivers the set of services (semantics space)
  - Service matching done between registered and published services
- She securely subscribes to the relevant offered services
  - For instance his office is activated (light, heating, computer, applications…) the post-robot delivers his mail and he receives a live video of his room and dynamic contents on his PDA as soon she enters. When moving in the building the relevant content is dynamically pushed towards her PDA.

2. The STIR Protocol

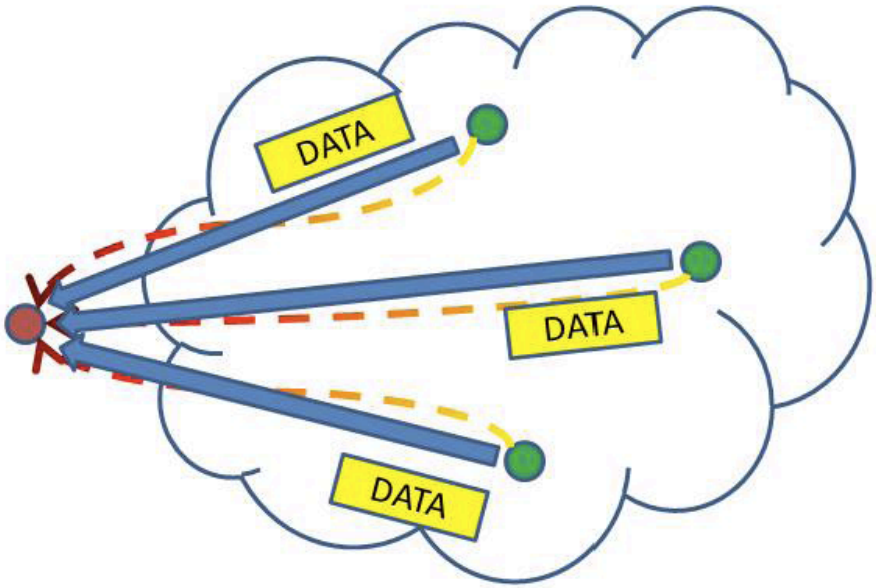
STIR in a NutShell (1)

- Interest diffusion and gradient field establishment using binary Spray and Wait
- Gradient reinforcement/ reduction techniques according to spatio-temporal events used as parameters of a utility function.



STIR in a NutShell (2)

- Content diffusion follows highest gradient slope with a modified version of binary spray and wait



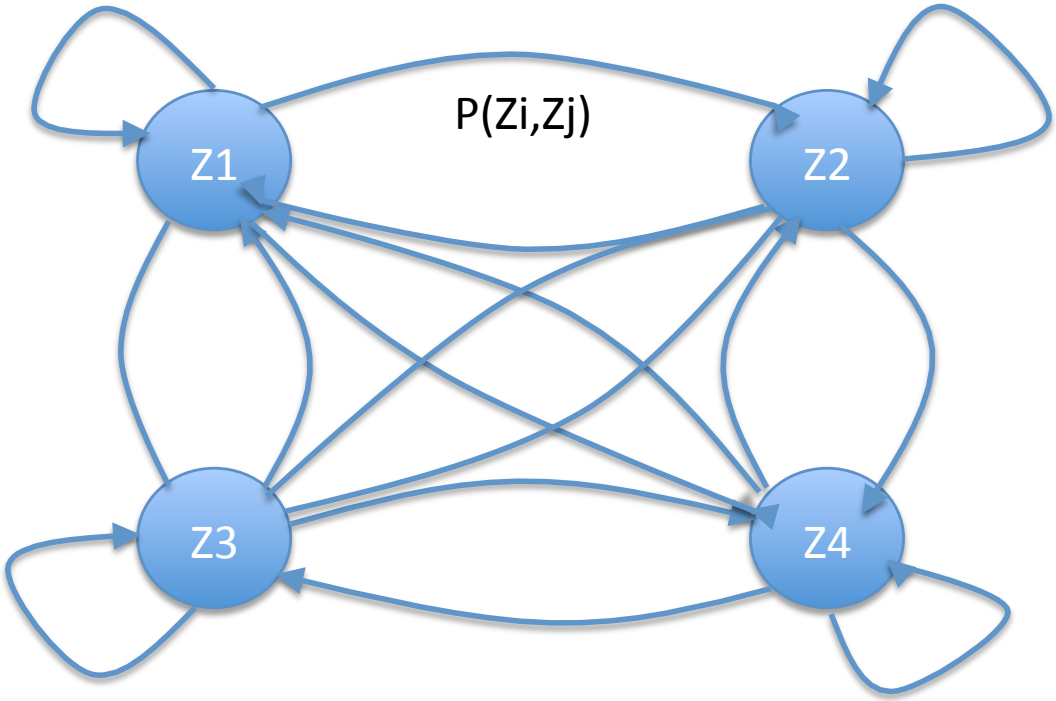
3. STEPS in a Nutshell

Modeling ST Correlation

- An abstract and parametric model of mobility for expressing ST correlation between nodes
- Every user/object has one or several preferential zones
- RWP mobility model in each zone
- Probability of transition between zone conversely proportional to the distance from the preferential zone
- Two main distributions:
  - Exponential: $p(Zi,Zj)=\beta e^{-\alpha d(Zi,Zj)}$
  - Power law: $p(Zi,Zj)=\beta(1+d(Zi,Zj))^{-\alpha}$
- The α parameter make it possible to cover the whole spectrum of ST behavior from strongly correlated, $\alpha=+\infty$, to no correlated at all $\alpha=0$ (from sedentary to nomadic behavior)

Modeling ST Correlation with STEPS

Markovian modeling leading to stationary distribution and average occupation time (ergodicity)



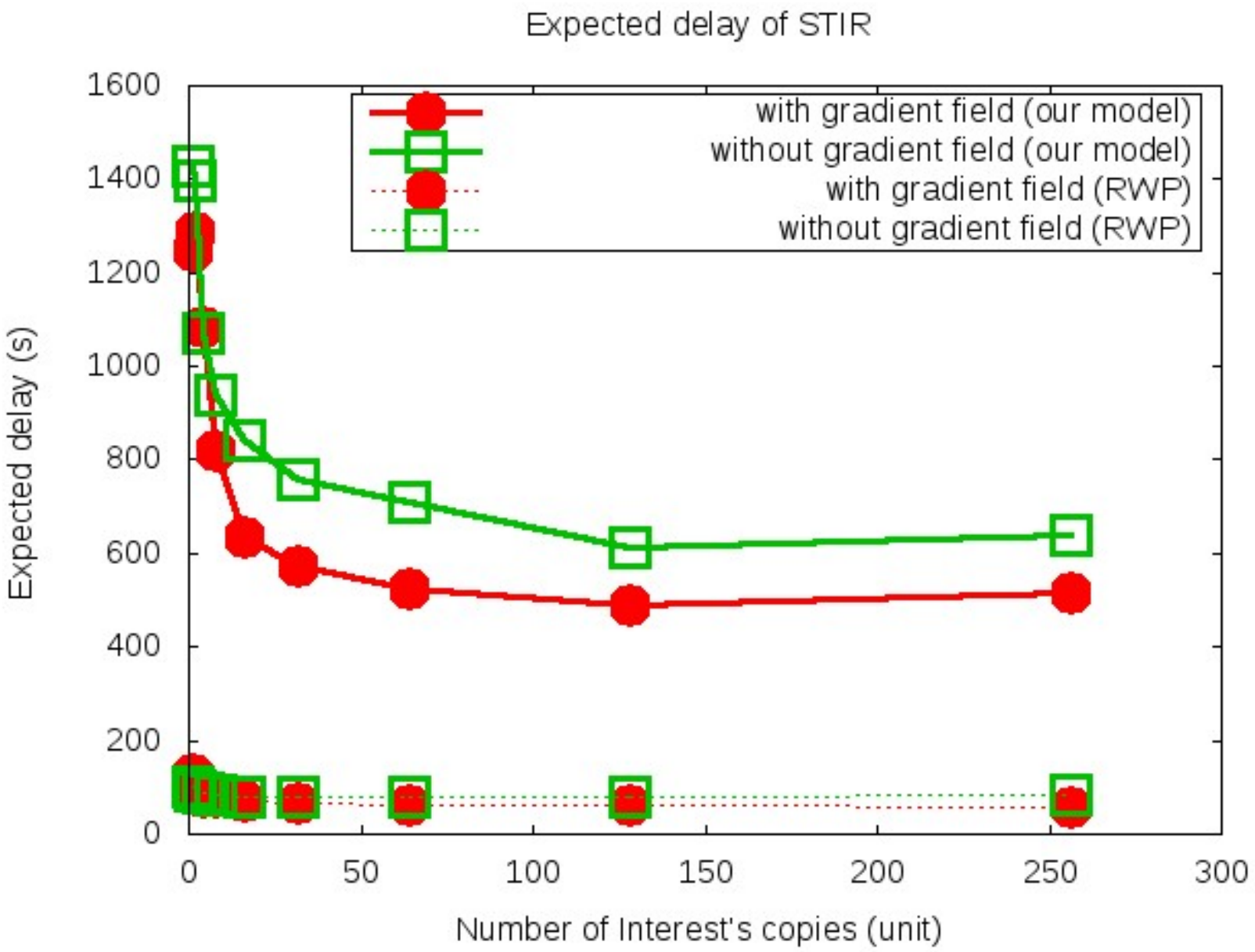
Mobility model and STIR implemented in The ONE network simulator

Simulation Results

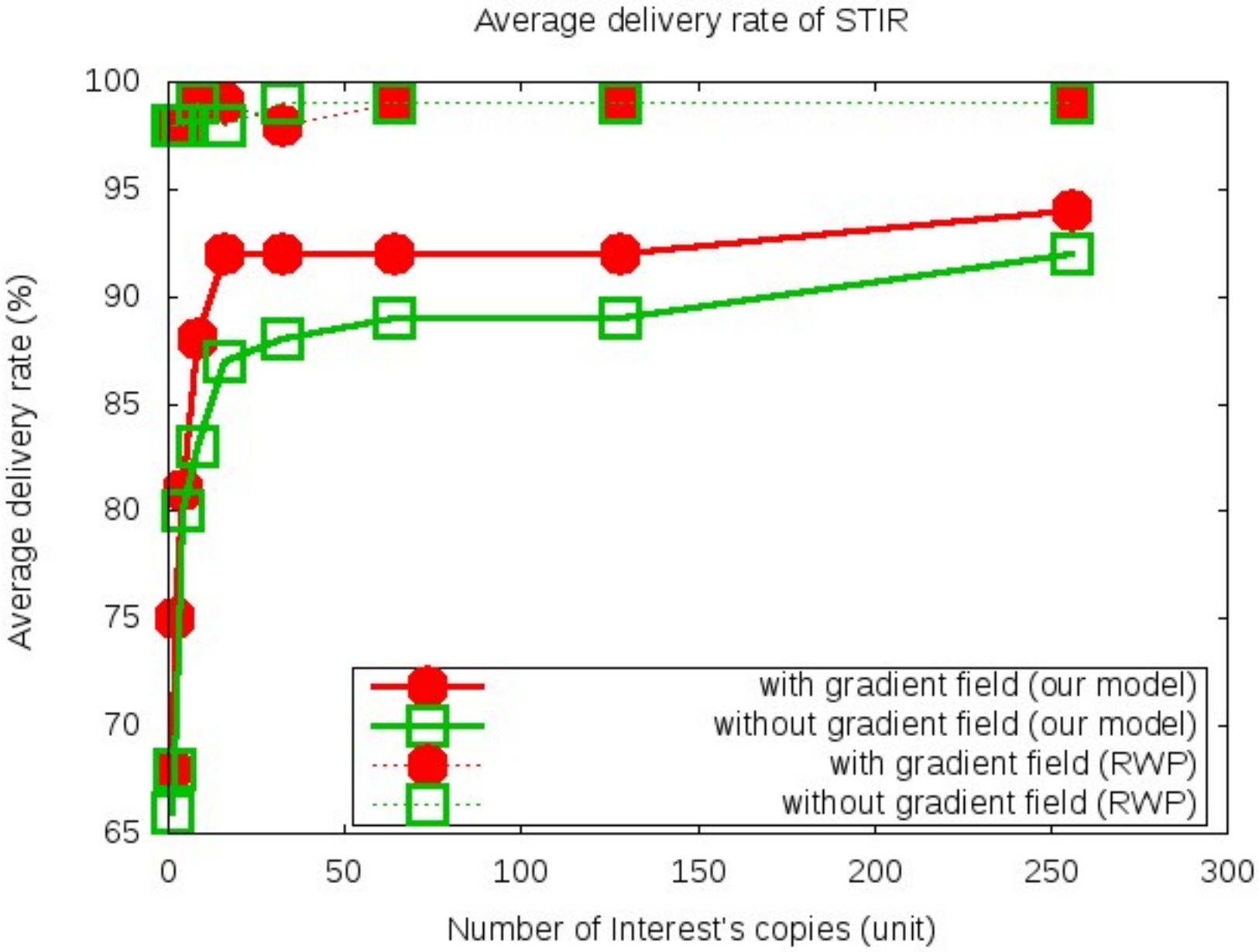
Simulations

- The One DTN Simulator
- Mobility according to the STEPS model
- Evaluation metrics
  - Delay
  - Delivery rate
  - Hop count
  - Sensitivity to ST correlation
- Simulations parameters
  - Node density 3000 nodes/sqm (medium city)
  - Man walk speed (5-10 km/h)
  - Communication radio range: 10 m
  - One service provider and one service user

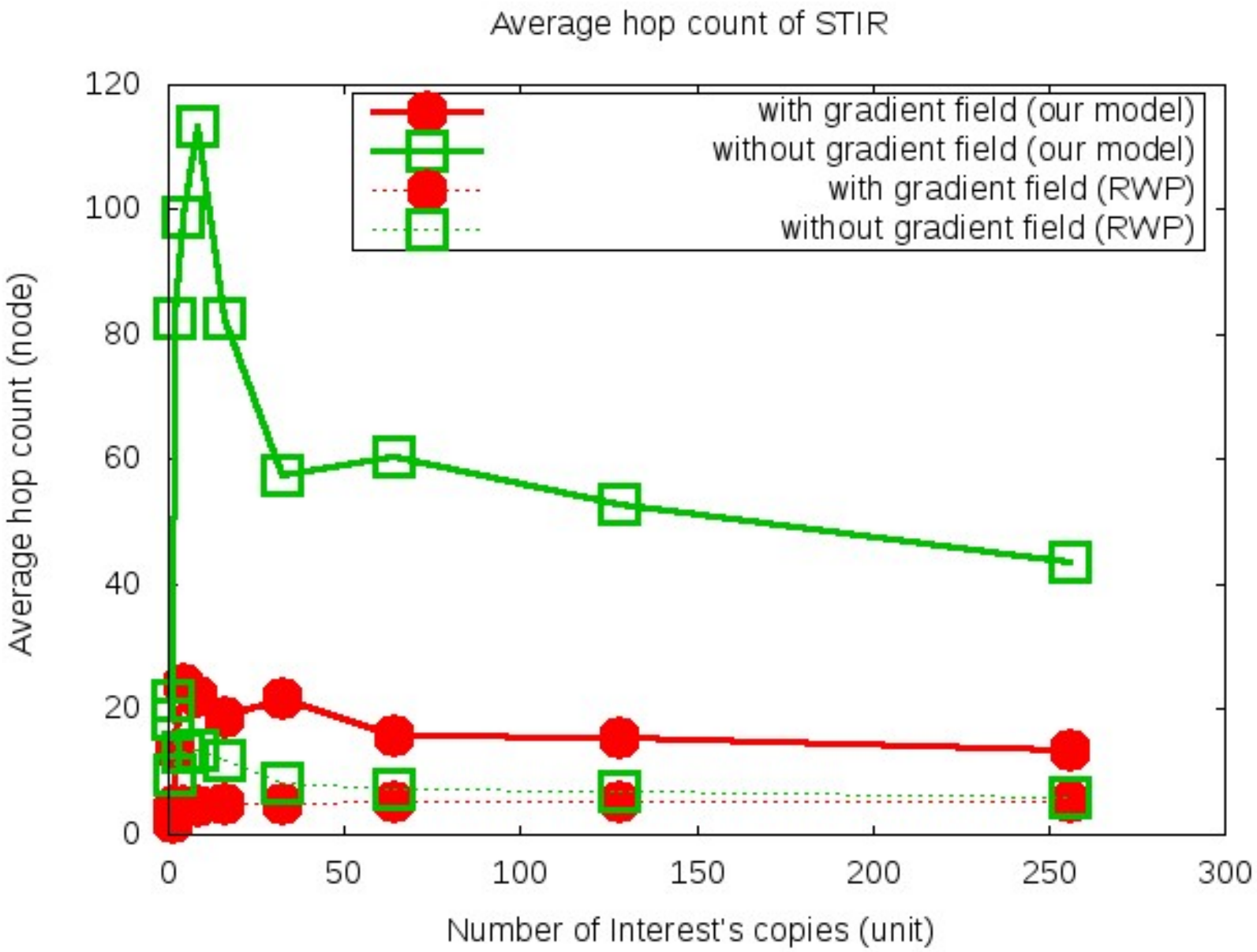
Global Delay



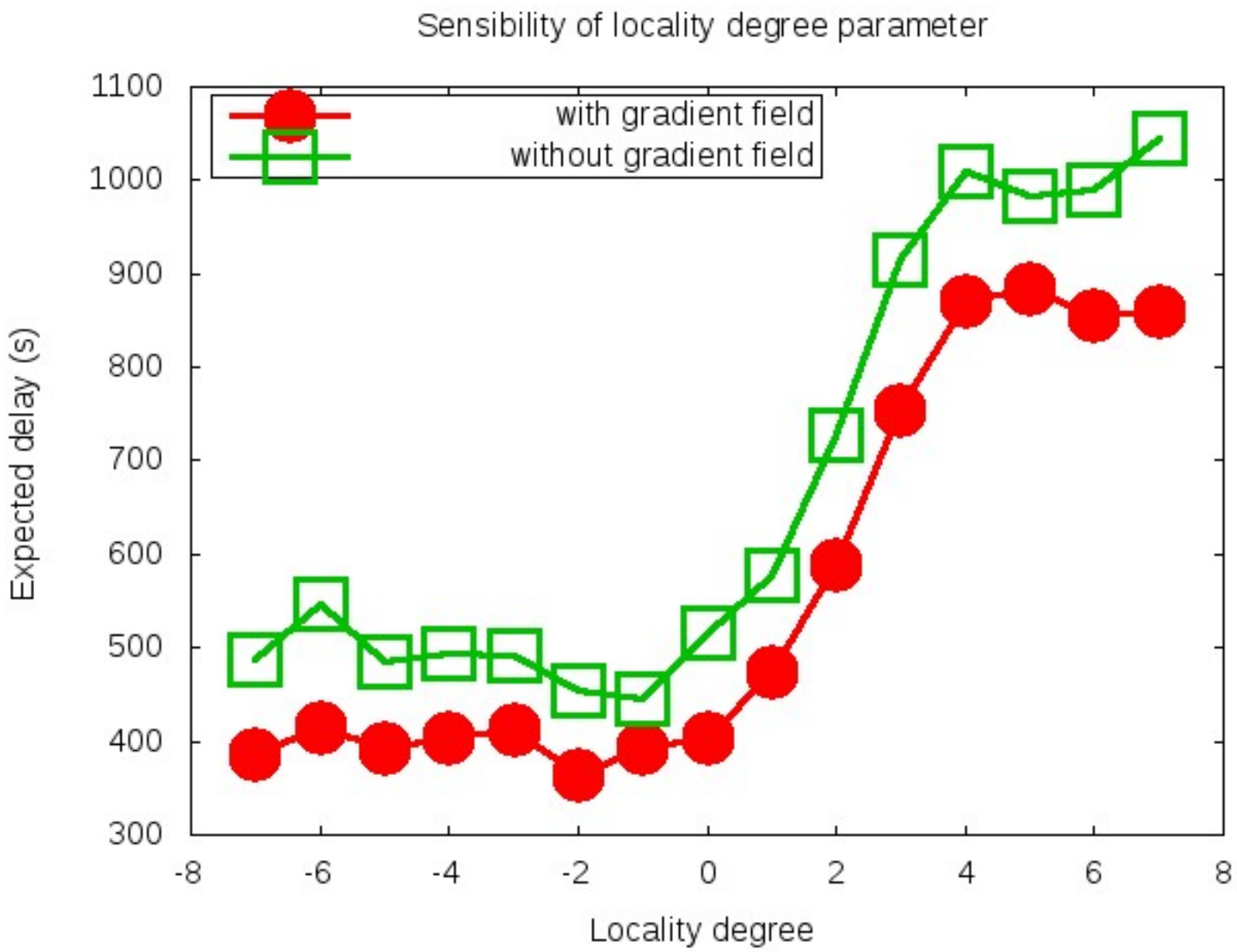
Delivery Rate



Hop Count


Average hop count of STIR
with gradient field (our model)
without gradient field (our model)
with gradient field (RWP)
without gradient field (RWP)
Average hop count (node)
Number of Interest's copies (unit)
0
20
40
60
80
100
120
0
50
100
150
200
250
300

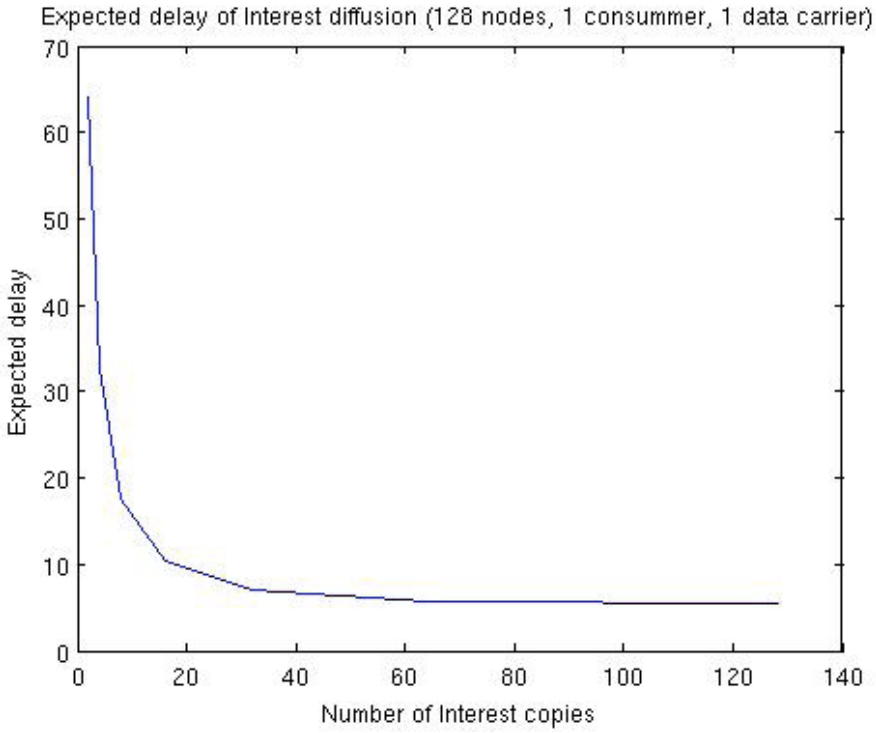
Sensitivity to Locality

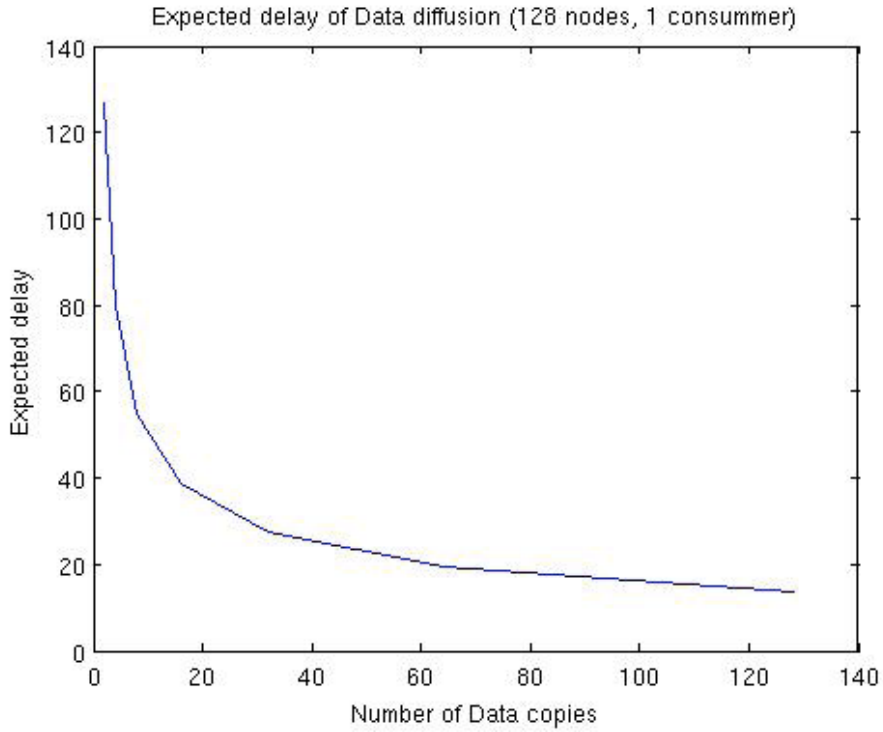


Conclusions and Perspectives

- Stigmergy based routing improves routing performances
  - Several utility functions to be experimented
  - Several interest diffusion and content diffusion mechanisms to be experimented
- STEPS offers a good modeling, abstraction and expressive power for the principle of preferential attachment
  - Small world emerging properties
  - Inter and intra contact time distributions fitting with mobility traces (power laws)
  - On-going work on routing performances comparison between real traces and STEPS.

Elements of Performance





Main Challenges (2)

- Secured access to service/content
  - Coupling of biometric (voice for instance) and traditional security mechanisms
- Traffic engineering
  - Define the optimal infrastructure mixing dedicated fixed infrastructure and spontaneous networks for QoS needs.
- Adaptive topology and protocols in response of users' needs and network state.
- Modeling and simulation of DTCCN
  - Mobility models