TAO

A Time-Aware Opportunistic Routing Protocol for Service Invocation in Intermittently Connected Networks

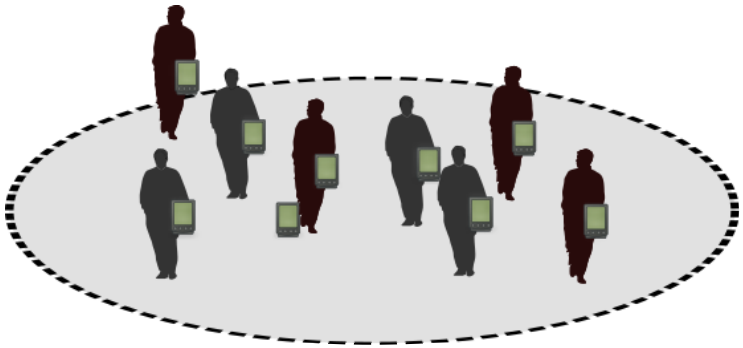
Ali Makke, Nicolas Le Sommer, Yves Mahéo

IRISA, Université de Bretagne Sud
France

Journées thématiques D2 IRISA, Rennes, 28-29 juin 2012

Outline

Mobile Ad hoc Networks

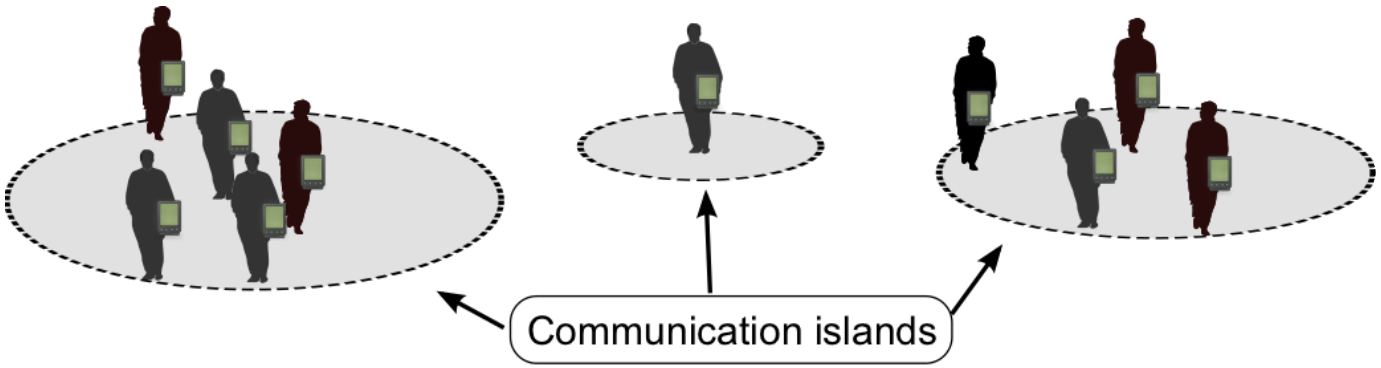


MANETs

- Collection of independent mobile nodes
- Communicate via radio
- Free to move in any direction
- Connected MANETs

Often, there isn't sufficient density to ensure connectivity

Intermittently Connected MANETs



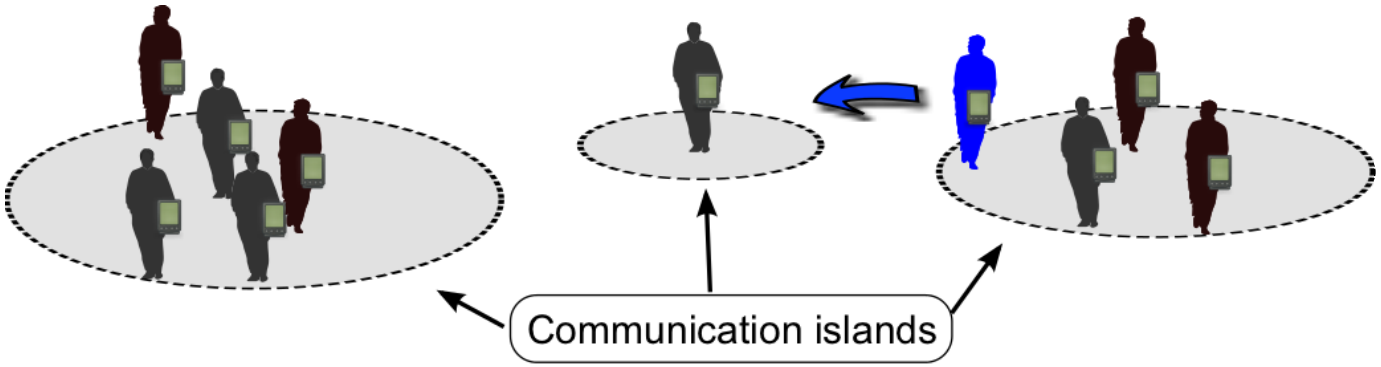
Intermittently Connected MANETs

- Distant islands of nodes
- Often impossible to maintain end-to-end path

DTN - Opportunistic Networking

- Store, carry and forward principle

Intermittently Connected MANETs



Intermittently Connected MANETs

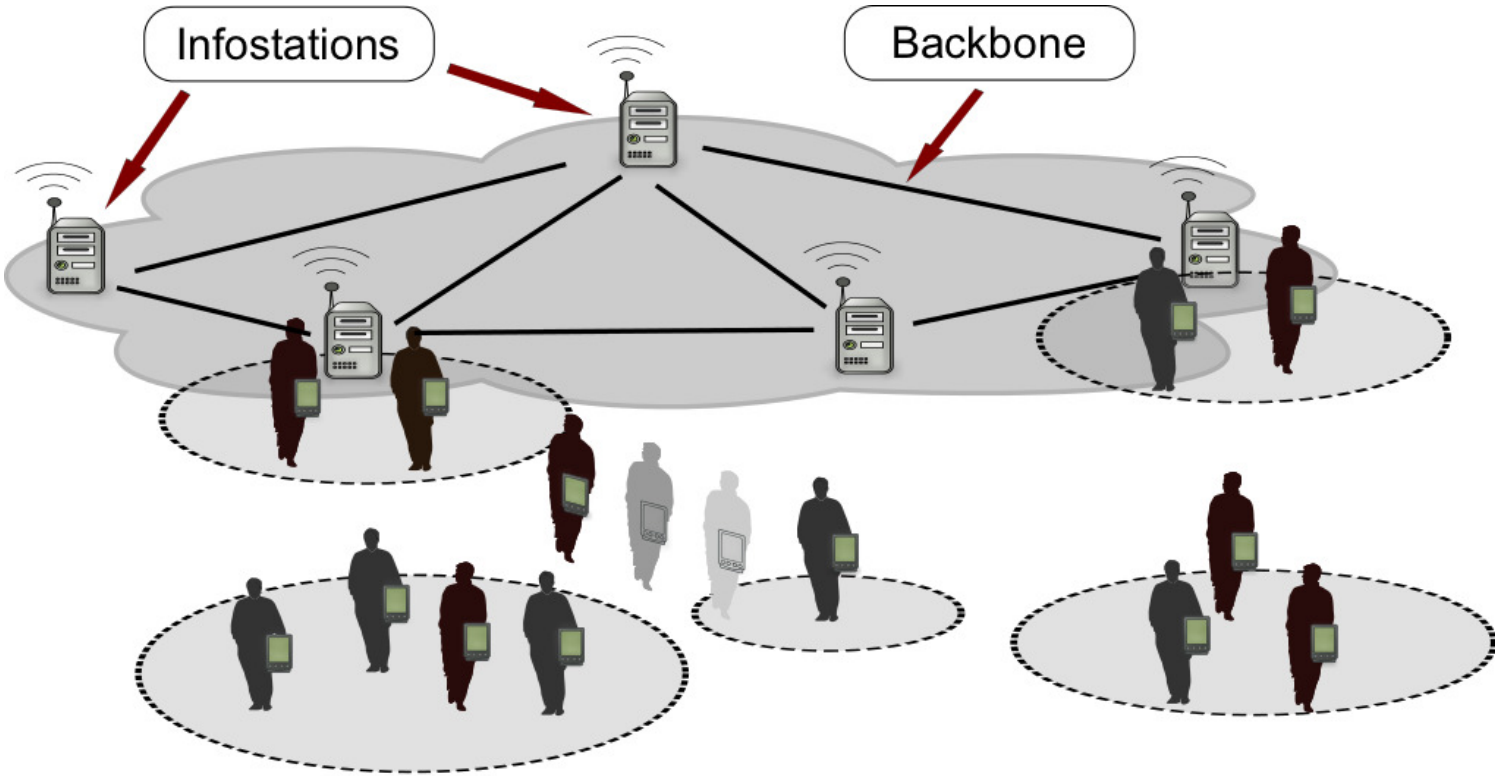
- Distant islands of nodes
- Often impossible to maintain end-to-end path

DTN - Opportunistic Networking

- Store, carry and forward principle

Intermittently connected Hybrid Networks (ICHN)

- Set of infostations connected together (or not) via a wired infrastructure
- Set of mobile nodes



Objective

Overall objective

Efficiently implement service oriented applications in intermittently connected MANETs

Objective of this specific work

- Propose a routing protocol that is able to implement service invocation in ICHN
- A mobile client invokes a service from a fixed infostation and receives the response of this invocation back

TAO

Time-aware Opportunistic Routing Protocol

- TAO is designed for service invocation in ICHN
- Time-heuristic: Dates of contacts of mobile nodes with infostations

TAO

Time-aware Opportunistic Routing Protocol

- TAO is designed for service invocation in ICHN
- Time-heuristic: Dates of contacts of mobile nodes with infostations

Concepts

- Good Carrier
  - Contact Date (Carrier/Infostation) > Contact Date (Local Node/Infostation)
  - Each node records only the last date of contact with an infostation
- Bad Carrier
  - Contact Date with an infostation is obsolete
- Local stock of messages
  - Limited number of messages dedicated to Bad Carriers

TAO

Time-aware Opportunistic Routing Protocol

- TAO is designed for service invocation in ICHN
- Time-heuristic: Dates of contacts of mobile nodes with infostations

Concepts

- Good Carrier
  - Contact Date (Carrier/Infostation) $>$ Contact Date (Local Node/Infostation)
  - Each node records only the last date of contact with an infostation
- Bad Carrier
  - Contact Date with an infostation is obsolete
- Local stock of messages
  - Limited number of messages dedicated to Bad Carriers

Select the best next forwarder(s) among a set of neighbor nodes

TAO

TAO Implements

Store, carry and forward principle

TAO

TAO Implements

Store, carry and forward principle

Multiple-copy message forwarding algorithm

- Good carriers will always obtain a copy of service requests
- Bad carriers will obtain copies of service requests from the stock of copies dedicated to them

TAO

TAO Implements

Store, carry and forward principle

Multiple-copy message forwarding algorithm

- Good carriers will always obtain a copy of service requests
- Bad carriers will obtain copies of service requests from the stock of copies dedicated to them

Source routing mechanism

- Each invocation message registers the ids of its carriers (till reaching the infostation) in its header

TAO

TAO Implements

Store, carry and forward principle

Multiple-copy message forwarding algorithm

- Good carriers will always obtain a copy of service requests
- Bad carriers will obtain copies of service requests from the stock of copies dedicated to them

Source routing mechanism

- Each invocation message registers the ids of its carriers (till reaching the infostation) in its header

Time-stamping based heuristic

- Dates of contacts of mobile nodes with infostations

TAO

TAO is a reactive and event-driven protocol

TAO

TAO is a reactive and event-driven protocol

Forwarding of service invocation request

- Emission of an invocation request by a local client application
- Reception of an invocation request sent by a neighbor node

TAO

TAO is a reactive and event-driven protocol

Forwarding of service invocation request

- Emission of an invocation request by a local client application
- Reception of an invocation request sent by a neighbor node

Forwarding of service response

- Reception of a service response sent by a neighbor node

TAO

TAO is a reactive and event-driven protocol

Forwarding of service invocation request

- Emission of an invocation request by a local client application
- Reception of an invocation request sent by a neighbor node

Forwarding of service response

- Reception of a service response sent by a neighbor node

Management of neighborhood changes

- Arrival of a new neighbor node
- Disappearance of a neighbor node

Forwarding of Service Invocation Requests

A copy of each invocation message will be forwarded to a limited number of direct neighbors

A Good carrier will always obtain a copy of an invocation request

Bad carriers will receive copies from the stock of copies dedicated to them

```
if there is an infostation in the one-hop neighborhood
  Forward Request to the infostation
else
  Check neighbors for good carriers
   if good carriers are found
    Forward a copy of the Request
    Update the best contact time with an infostation relative to this Request
   else
    if Local stock of the Request > 0
      Forward a copy of the Request to a bad carrier
```

Evaluation

First Objective

Assess the effectiveness of the time heuristic used in TAO

Evaluation

First Objective

Assess the effectiveness of the time heuristic used in TAO

Simulation Using OMNeT++ Network Simulator

Comparison

TAO

Relies on the time heuristic to choose next carriers among neighbors

RANDOM

Relies on a random choice of the next carriers among neighbors

Evaluation

First Objective

Assess the effectiveness of the time heuristic used in TAO

Simulation Using OMNeT++ Network Simulator

Comparison

TAO

Relies on the time heuristic to choose next carriers among neighbors

RANDOM

Relies on a random choice of the next carriers among neighbors

Metrics Used in the Evaluation

- Global Satisfaction Ratio
- Average Delay

Scenario and Parameters

Scenario

- 1 fixed infostation in a 1 km^2 area
- Number of mobile nodes varies from 10 to 300
- Clients are a subset of the mobile nodes
  - Number of Clients varies from 10 to 60

Scenario and Parameters

Scenario

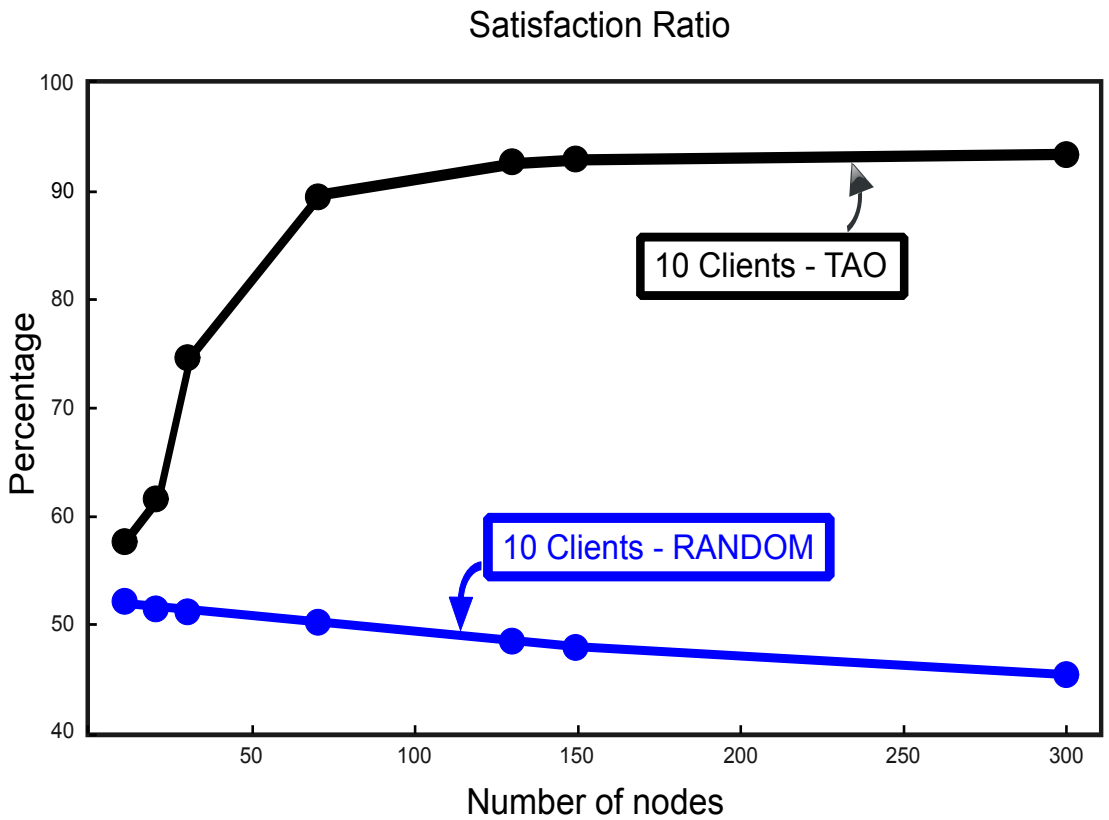
- 1 fixed infostation in a 1 km^2 area
- Number of mobile nodes varies from 10 to 300
- Clients are a subset of the mobile nodes
  - Number of Clients varies from 10 to 60

Parameters

- Communication range of infostation and mobile nodes 30 m
- Properties of mobile nodes
  - Speed of mobile nodes 0.5 m/s
  - Mobile nodes move in a random waypoint mobility model
- Local stock of each message 3 (TAO and RANDOM)
- Duration of each simulation 80 minutes
- A client invokes a service every 3 minutes

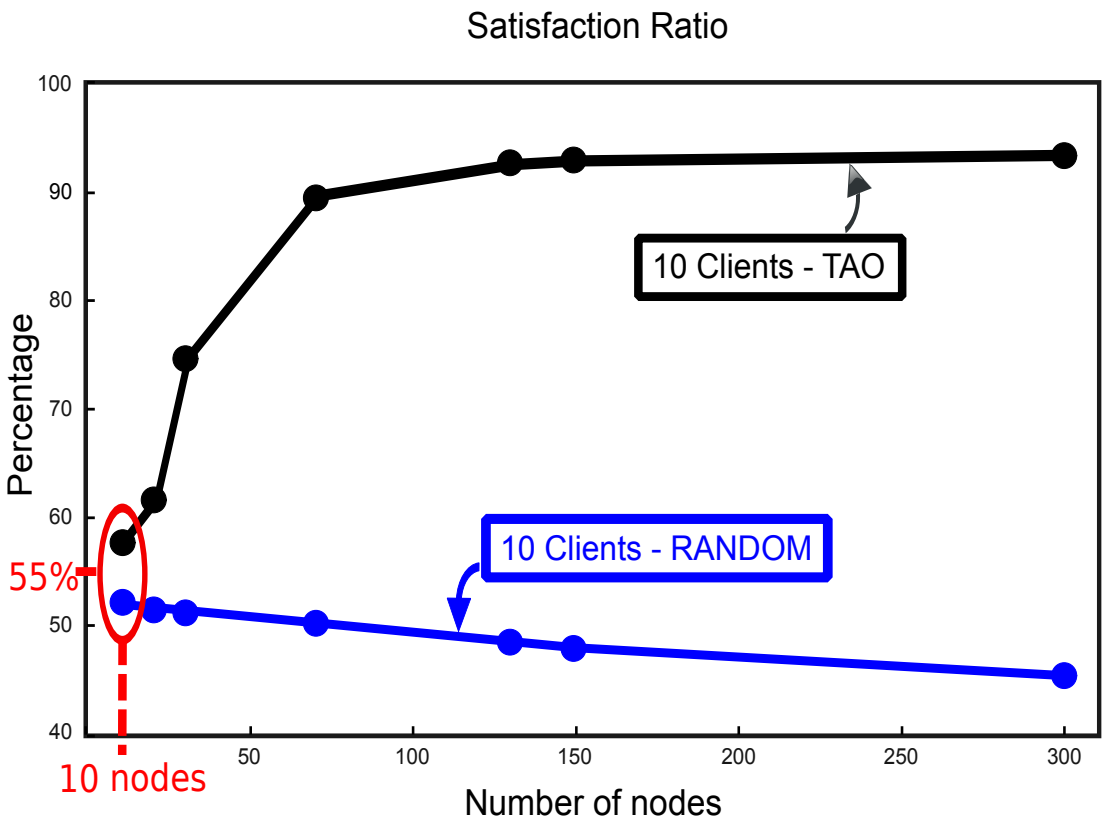
Results: Global Satisfaction Ratio

Satisfaction Ratio: percentage of successful service invocation



Results: Global Satisfaction Ratio

Satisfaction Ratio: percentage of successful service invocation

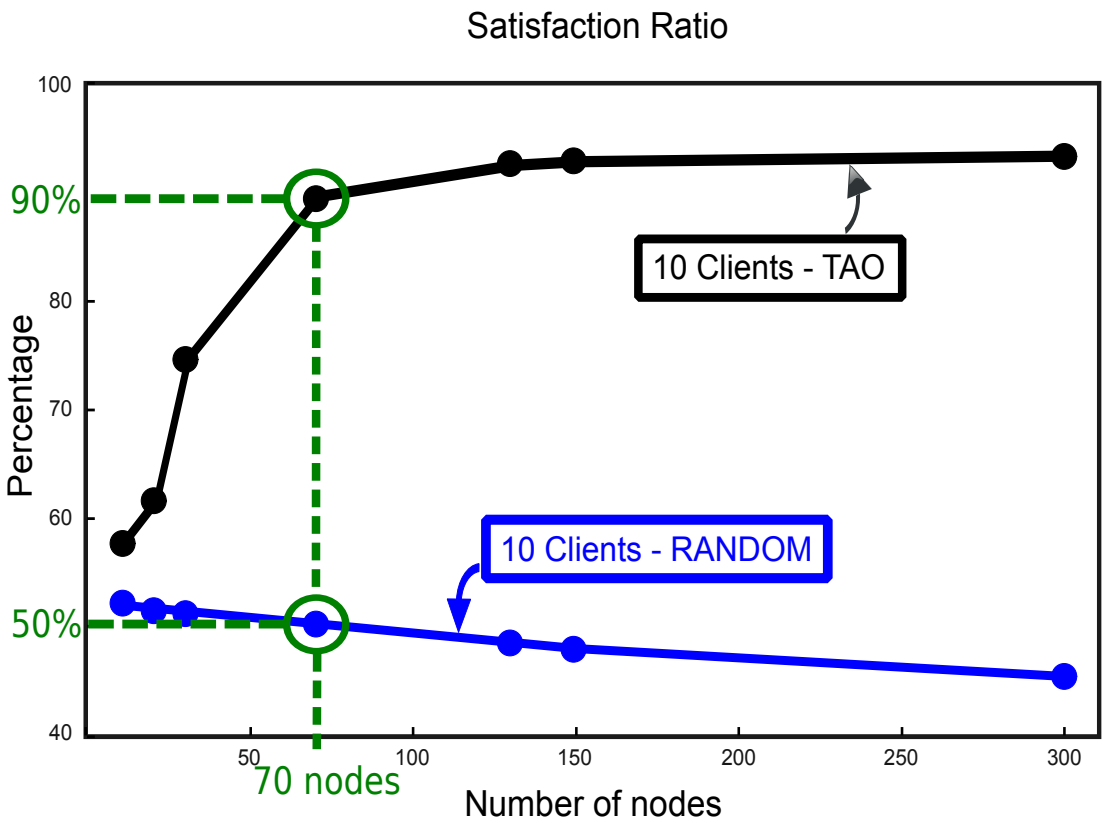


Limited number of neighbors

TAO & RANDOM select almost the same carriers

Results: Global Satisfaction Ratio

Satisfaction Ratio: percentage of successful service invocation

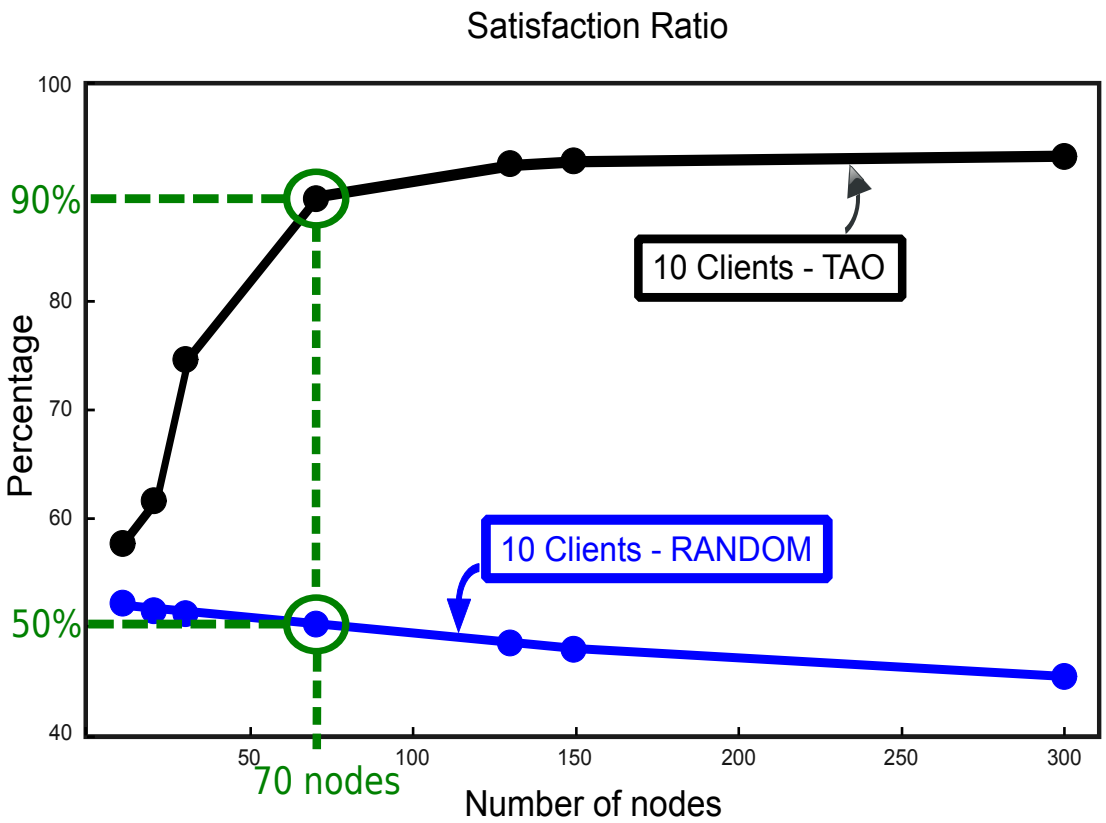


TAO performs GOOD selection of carriers

RANDOM performs BAD selection of carriers

Results: Global Satisfaction Ratio

Satisfaction Ratio: percentage of successful service invocation



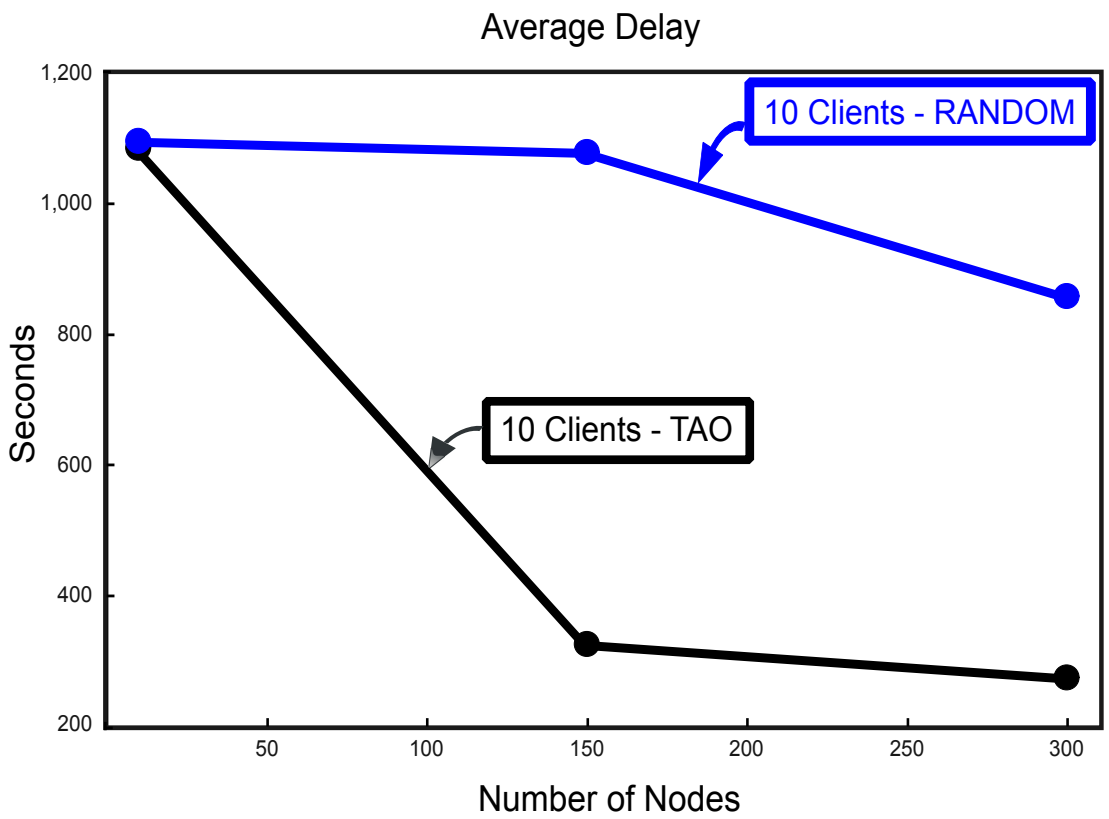
TAO performs GOOD selection of carriers

RANDOM performs BAD selection of carriers

Performance of TAO increases quickly with the number nodes in the network

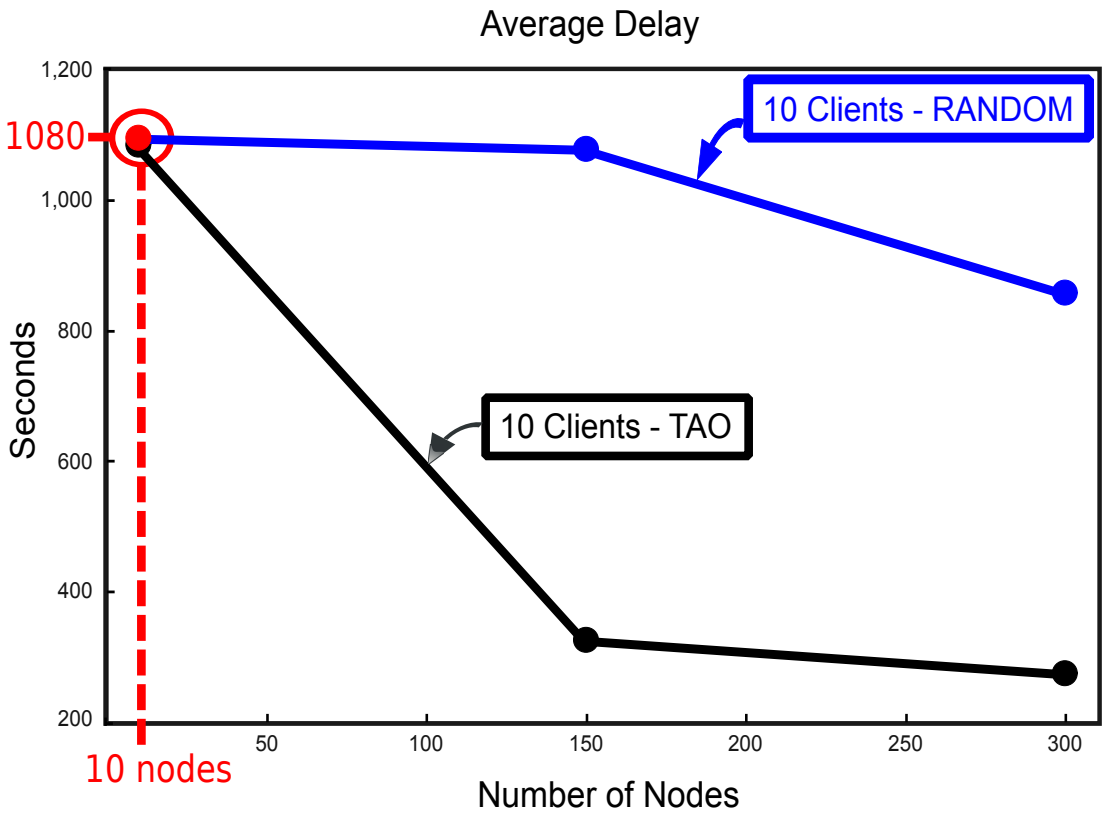
Results: Average Delay

Average delay: Round trip time of a message between a Client/Infostation



Results: Average Delay

Average delay: Round trip time of a message between a Client/Infostation

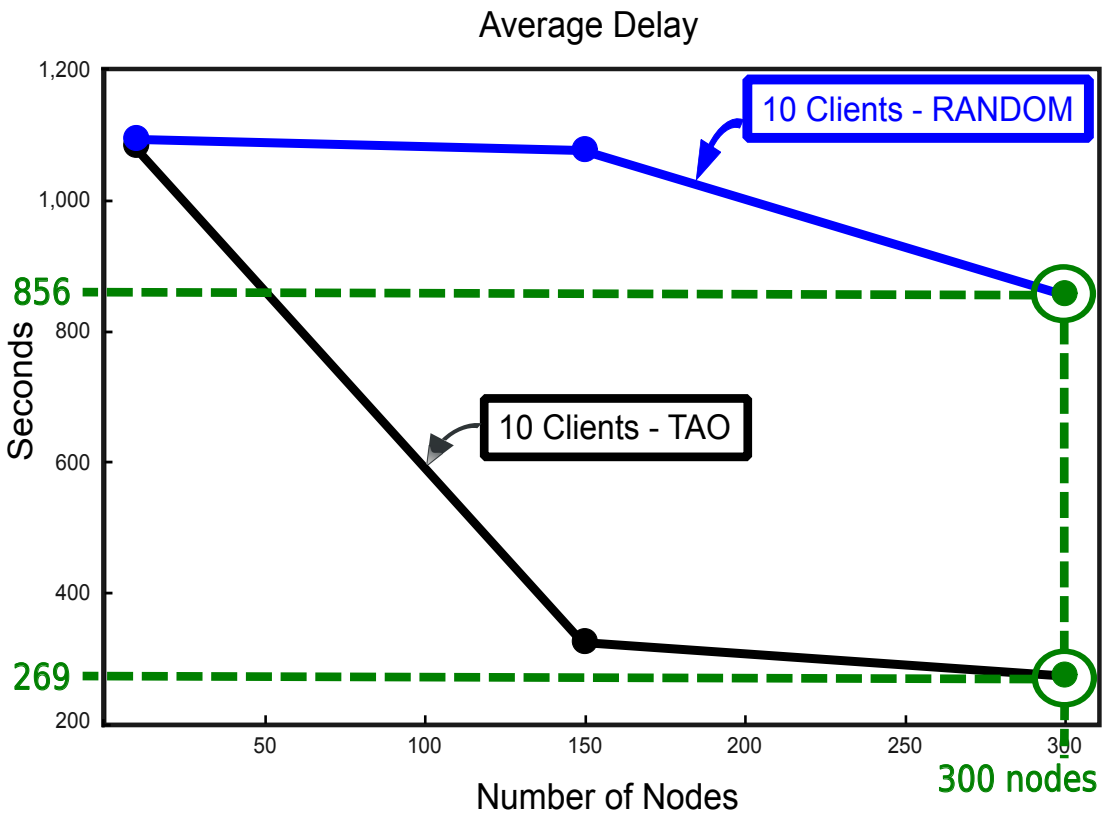


Few nodes with limited transmission range

Relatively high delay values

Results: Average Delay

Average delay: Round trip time of a message between a Client/Infostation

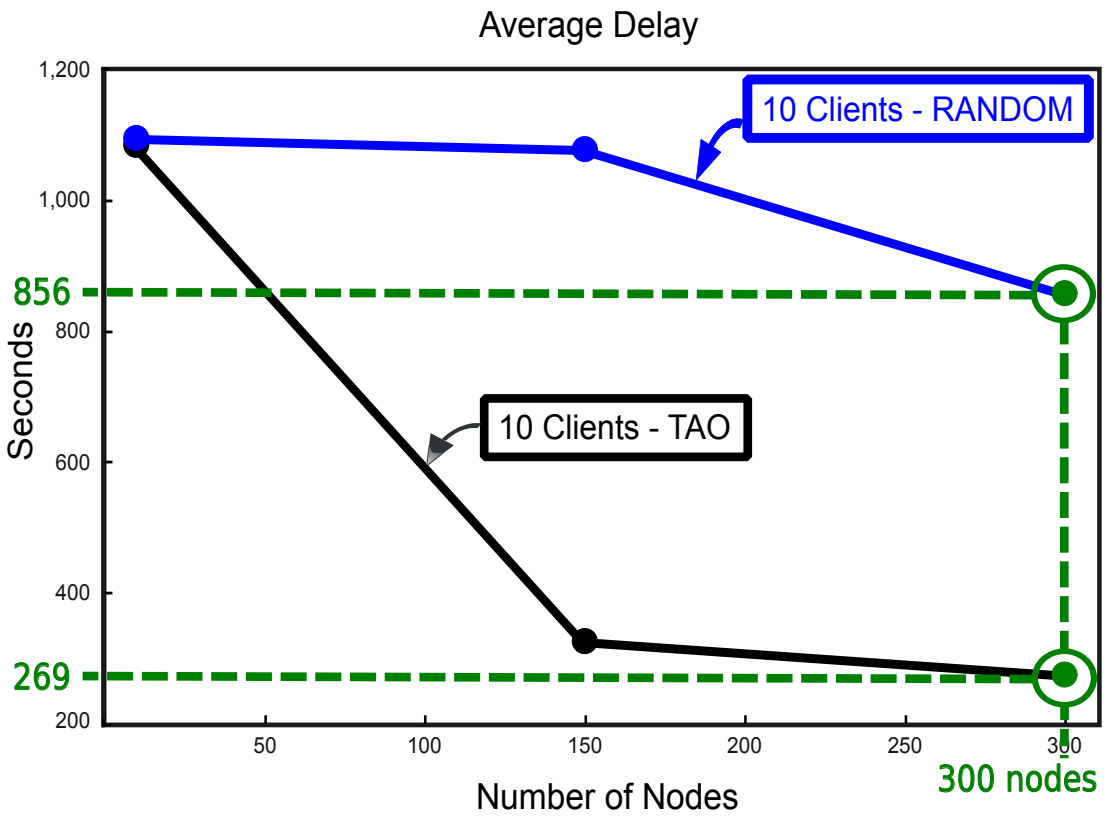


More nodes fill the gap between the clients and the infostations

The choice of carriers plays an important role

Results: Average Delay

Average delay: Round trip time of a message between a Client/Infostation



More nodes fill the gap between the clients and the infostations

The choice of carriers plays an important role

TAO quickly achieves shorter delays and higher delivery ratio

Conclusion

Summary

- Intermittently connected hybrid networks an original perspective
- A time-aware opportunistic routing protocol (TAO) for service invocation dedicated to ICHN
- Time-heuristic effectiveness evaluation

Future Work

- Comparing TAO with other well known routing protocols (PRoPHET)
- A handover mechanism between infostations
- Support service discovery in TAO

TAO

A Time-Aware Opportunistic Routing Protocol for Service Invocation in Intermittently Connected Networks

Ali Makke, Nicolas Le Sommer, Yves Mahéo

Thank you!

Questions?

http://www-irisa.univ-ubs.fr/Ali.Makke

Forwarding of Service Responses

Infostation sends the reply message using reverse source routing

Disconnection encountered

- A multiple-copy message forwarding algorithm is performed
- Resume reverse source routing

```
if original-service-requester is a direct neighbor
  Forward Reply to the requester
else
   if next id recorded in header is a direct neighbor
     Forward Reply
   else
     if any id recorded in the header is a direct neighbor
       Forward a copy of the Reply
```

Management of Neighborhood Changes

Node/infostation joins neighborhood

Node conditionally forwards copies of Requests/Responses to the new neighbor

Node/infostation disappears

All related information will be removed from the internal lists of the node

```
if the event is arrival
  if the new neighbor is a good carrier or size of stock > 0
    foreach valid request in the local cache
      Forward request to the new neighbor
    foreach valid response in the local cache
      Run algo: "Forwarding Service Response"
```