1 Introduction

The workshop “Supporting Context-aware Collaborative Applications in Mobile Ad Hoc Networks” was organized following an initiative of the MiNEMA program which aims on fostering research cooperation between young researchers on a particular research theme related to middleware for mobile ad-hoc networks. The concrete theme of this workshop was previously determined by a proposal written by the researchers who intended to participate in the workshop. The theme of the workshop can be best characterized by the following paragraph taken from the proposal:

The spread of powerful mobile devices along with the emergence of mobile ad hoc networks (MANET) enable new forms of mobile collaborative applications involving interactions between users in the proximity (small-scale ad hoc networks) as well as at different locations (large-scale ad hoc networks). Support for context-awareness on mobile devices further creates opportunities to collect and share information about the surrounding environment in order to enhance coordination. This can be especially useful for applications where the decision of one participant depends (i) on the current environmental conditions, and (ii) on the actions of other users.

The main objective of this workshop has been in discussing research issues related to the theme and work out a more concrete scenario by considering the background and expertise of each participants. This way the foundations towards more concrete scientific results and future cooperations were supposed to be established.

This report gives an overview about the workshop activity as well as how the workshop is going to impact on future research cooperations. Preliminary results will be given in a position paper in the appendix of the report.

2 Participants

The participants were:
• Paolo Costa (Politecnico di Milano): his main research interests focus on epidemic protocols, content-based routing protocols for dynamic networks, including peer-to-peer networks, mobile ad hoc and sensor networks.

• Daniela Gavidia (Vrije Universiteit Amsterdam): 

• Boris Koldehofe (University of Stuttgart): his main research interest include adaptive, scalable and fault-tolerant communication protocols on support for cooperative interactions.

• Hugo Miranda (University of Lisbon): his main research interests include epidemic protocols, trust and fairness in mobile ad hoc networks, adaptive middleware.

• Oriana Riva (Department of Computer Science, University of Helsinki): her main research interests include context-awareness and applications in mobile ad hoc networks.

The proposal for the workshop was prepared in conjunction with Mirco Musolesi and Sasu Tarkoma who could not take part to the workshop.

3 Workshop Description

The workshop was held at the Helsinki Institute for Information Technology (Finland) on Sept 15-16th. During the first day, each participant gave a short presentation about his research interests and also proposed potential topics to discuss during the workshop. Upon this general overview, we first identified a common use case to be used as reference example during the discussion. We then passed to identify challenging issues to be addressed in order to accomplish such a scenario. These research problems were then discussed in more detail during the second day. In attachment to this report there are agenda and presentations given by each participant.

4 Workshop Results

In many applications human users require information suited to their context. Often the information is only needed during a short time, but needs to provide a sufficient level of accuracy. In highly dynamic and large community systems, it may be doubted that purely infrastructure based solution can be deployed such that those serve the individual demands of the users. Especially, if we consider information which is relevant to geographical coordinates it may be hard to monitor, store and process information such that it could yield a large variety of constraints and fully cover densely populated areas. We may face challenges as coverage and bottleneck of servers. Instead we may need to rely on users collaborating in order to find and retrieve information relevant to each other.

In this workshop we looked into the research challenges of how mobility can be useful in supporting applications that rely on cooperative context-aware information provisioning. We aim at exploring these issues in the context vehicular ad-hoc networks since many interesting cooperative application can be seen in the context of traffic low and control.
The workshop allowed to create a core of European young researchers strongly committed and motivated for cooperating. To bootstrap cooperation, the group identified a research topic suiting the interest and research expertise of all participants and established a number of mid-term goals that will allow to assess progress.

Joint research will be focused on vehicular networks, a particular subject of mobile computing where the different expertise of the participants can be combined in a fruitful joint collaboration. Vehicular networks are a promising field which presents both interesting research challenges that match the expertise of the participants and immediate application in one of the most innovative and competitive industries.

Vehicular ad hoc networks provide also many interesting and helpful properties which can be used to support such applications. Our focus will be on supporting queries which allow cooperation and allow the user to specify which information.

As a preliminary step, the group defined a use case including problems that are not well solved in the literature. These problems will be used as a motivation for a position paper to be submitted to a specialized workshop in vehicular networks.

5 Future Collaboration

The group agreed on an agenda that expresses members commitment for continuing cooperation. Among others, the agenda includes the following items:

Setup of a cooperative research environment that includes a shared workspace for the exchange and preparation of documents and a discussion forum;

Seek of additional partners To broaden the field and that may help to materialize the research projects for example by providing funding and/or feedback about research in progress.

Submission of a position paper to some specialized workshop on vehicular networks. The preparation of the paper will allow to clarify the contribution of each member and will require a systematic analysis of the state of the art. Additionally, feedback from reviewers and from the other participants at the workshop would contribute for strengthening and tuning the goals of the project.

Carry on cooperation on other projects where the fields of expertise of the participants complement. These are expected to be carried by subgroups composed of 2 or 3 participants. So far 3 main subtopics have been identified:

- Ad hoc routing: Vehicular Ad Hoc Networks (VANETs) are a specific class of networks which enables car to car communication without relying on any fixed infrastructure. Compared with traditional Mobile Ad Hoc Networks (MANETs), routing is more challenging since the target scenario with thousands of vehicles calls for higher scalability than in typical MANET scenarios. This explains why we cannot
simply reuse the protocols devised for MANET and force us to in-
vestigate new approaches. On the other hand, energy constraints
are fewer, as nodes are continuously powered, thus enabling more
sophisticated routing strategies.

- **Trust and security**: Clearly, a large effort must be put in mak-
ing VANET protocols robust to security attacks. Indeed, given the
spread of vehicles nowadays, the impact of a security threat would
be tremendous. Hence, we plan to consider security already in the
early stage of our study.

- **Real mobility user models**: A key peculiarity of the VANET scenario
is that the movement of nodes is not random but, conversely, it can
be predicted, at least to some extent. There exists several research
projects which collect real traces, using wireless devices installed on
vehicles. We plan to ground on this results to derive ad hoc mobility
models, to provide a more realistic evaluation of our protocols.

6 Dissemination of Results

Currently no publications have been produced. In the near future, the posi-
tion paper will be extended and submitted for publication in order to receive
more feedback from the research community and assess in depth the feasibil-
ity of our project. In the long term, publications focusing on the mentioned
subtopics are expected to be submitted for publication in international confer-
ences/workshops.

7 Appendices

Appendices include agenda of the 2-days workshop, slides of each participants,
and current position paper.

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workshop and providing useful consultancy.
Minema Workshop

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I, me and myself

• Previously
  ▪ Ph.D. Student at Politecnico di Milano, Italy
  ▪ Research Area: Middleware for Dynamic Networks
    • Peer-to-peer Networks, Mobile Ad Hoc Networks and Wireless Sensor Networks

• Now
  ▪ Post-doc researcher at VU in Amsterdam
  ▪ Main topic: Grid-computing for large scale networks
  ▪ not related to this workshop :’( 

• More info at http://www.paolinux.net
Content-based Routing

- Messages are routed based on their content rather than their destination address.
- Components are loosely coupled:
  - well-suited for dynamic scenarios
- Traditional approaches (deterministic) barely tolerate reconfigurations.
- Epidemic (probabilistic) protocols work well but may introduce high overhead.
A semi-probabilistic approach combining:
- the efficiency of deterministic routing
- the resilience to reconfiguration and inherent simplicity of probabilistic approaches

Deterministic information is maintained only in the proximity of the subscriber.

Evaluated on:
- p2p Networks (link-based)
- MANET (broadcast-based)
- WSN (broadcast-based)
Delay Tolerant Networks

- Delay Tolerant Networks (DTN) are characterized:
  - long delay paths
  - frequent long duration partitions
- Information carried by a mobile node and forwarded opportunistically across partitions
  - allows communication between areas that are never connected by an end-to-end path
- SPCAST/DTN (with Mirco)
  - subscription information are integrated with host mobility and connectivity changes history
  - Kalman filters exploit this information to identify potential carrier hosts
Wireless Sensor Networks

- **TeenyLIME**
  - tuple-space based middleware for wireless sensor networks
  - transiently-shared tuple space
  - implemented in TinyOS
- **Remote Control and Debugging**
  - network discovery
  - sensor reading
  - code update
  - application introspection
- **Component-based Reflective Middleware**
  - inspectable, adaptable and extensible at runtime
  - developed in Java, C/Unix and C/Contiky
Vehicular Ad Hoc Networks

• Vehicles may propagate information about potentially dangerous events
  ▪ lane changes
  ▪ sudden slowdowns to vehicles in their vicinity
• The approach is based on a propagation function encoding:
  ▪ the destination areas of each message
  ▪ the roads it should follow to reach such areas
• This allow for selectivity as well as efficiency in terms of network traffic
So what?

- Supporting Context-aware Collaborative Applications in Mobile Ad Hoc Networks
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- Start from the application (i.e. the problem) not from the solution
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- Start from the application (i.e. the problem) not from the solution
- Interaction with the surrounding environment
So what?

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- Interaction with the surrounding environment
- Decentralized approach
So what?

- Supporting Context-aware Collaborative Applications in Mobile Ad Hoc Networks
- Start from the application (i.e. the problem) not from the solution
- Interaction with the surrounding environment
- Decentralized approach
- No fixed infrastructure (almost)
Proposal

- Vehicular Ad Hoc Networks
  - industry does care
    - Toyota, BMW, Fiat, ...
  - context matters
    - free parking, nearby restaurants, traffic jam
  - very large scale networks
    - collaboration is key
    - centralized solutions based on fixed infrastructure are too expensive
Multiple Perspectives

- Application
- Middleware services
- Routing protocols
- Networking issues
- Trust, fairness and security
(Daniela is responsible too 😊)

Query / Advertisement on VANETs
- GPS navigators select the shortest route
  - ✗ traffic is not taken into account → not always the best option
  - ✓ need to know when traffic gets congested
- they also provide information on nearby points of interest
  - ✗ information gets obsolete rather soon
  - ✓ need to find open restaurants / available parking slots
- ...

Mobile Bloggers
- advertise yourself, know people around you
- brand new experience

Spam detection based on reputation
- filter out VIAGRA advertisements (unless needed :P)
- I trust you because many people do
A Gossip-based Distributed News Service for Wireless Mesh Networks
Example: Shopping Center

Mesh routers (located at stores)
Mesh clients (carried by costumers)
Example: Shopping Center

News items gossiped through Mesh Backbone
Client receives items from nearby router
Canning Spam in Wireless Gossip Networks
Performance on the client side

- Probability of seeing an item:

\[ p(k, c, d) = 1 - \prod_{i=1}^{k} (1 - \text{prob\_success}(i)) = 1 - \left(1 - \frac{c}{d}\right)^k \]

Graphs showing probability and recall rate for different cache sizes.
Model

- Communicate wirelessly with neighbors
- Each node has limited storage
Characteristics of the gossip network

• Collective storage space is divided between published items:
  ♦ Items are replicated according to the available storage space.
  ♦ More items => less replicas per item.

• Each node can have only a limited number of items in the network at a time.
Malicious Behavior

- Malicious nodes corrupt all items that pass through.
- Intent: advertise something or pollute the network.
Effect of malicious nodes (1%)
Probabilistic Verification

$p = 0.0$

$p = 0.05$

$p = 0.30$
Problem

$p = 0.30$

Still checking at 30 %
Collaborative applications?

• Wikis, shared spreadsheets, shared calendars.
• Mobile environments:
  ⊗ One-to-many communication.
  ⊗ Context is important (position, distance between nodes).
  ⊗ No central control.
Information dissemination for large-scale collaborative applications

Boris Koldehofe
Outline

- Some view of mine on collaborative environments
- Examples of my work on the communication aspects
  - Epidemic event dissemination
  - Decentralised Cluster Management
- Sketches for Ideas
A general view on collaborative environments

- Possible applications with physically distributed “users” or processes:
  - Conferencing, CVEs
  - Simulation, Training, Entertainment
  - Administration of distributed (e.g. telecom, transport) systems
Supporting cooperation in distributed systems

- Trade-off
  - Overhead vs. Consistency
  - Scalability vs. Reliability

- My Focus is on:
  - Group Communication
  - Publish/Subscribe
  - Management of Resources
Model and Methods

- Decentralisation
  - Support Scalability
  - Fault-tolerance
  - No control of a single entity wanted
- Consider Resource Restrictions
  - Views, Buffer sizes are limited
  - “optimistic guarantees”
    - Express reliability with high probability
    - Support scalable ordering of events,
      - Optimistic causal order
- Provide additional control
  - Management of resources with decentralised clusters
Example: Epidemic event Dissemination

- Analysis with balls and bins
- n bins ~ n processes
- m balls ~ a single event

Round 1:
create $m_1$ balls

Round 2:
create $m_2$ balls

... 

Round $r$:
create $m_r$ balls

$m_1 + m_2 + \ldots + m_r > cn \log n$ balls, $c > 1$

$\Rightarrow$ every bin contains at least one ball w.h.p.
Example 2: Ring-based Cluster Management

- Idea: Tickets grant access to a resource
  - Number of tickets ~ concurrency

- Management: Ring Structure
  - Processes form a cycle (max n)
  - Predecessor and successor are determined by the ticket a process obtained
  - Each process manages entries in between its own ticket and its successor ticket.

- Lightweight control mechanisms
  - Few updaters, but many readers
  - Support optimistic ordering
Towards Manets

- Previous approaches work well for infrastructure networks
  - Overlay balances communication
  - Failure has low impact on overall reliability
- What happens if the cost of the mapping matters?
  - What can we still guarantee?
  - Consider underlying physical connections
  - Decentralised resource management feasible?
- Some issues addressed in MiNEMA meeting in Leuven
Sketch for proposals

- Collaboration in Manets
  - Coordinate Decisions of physically distributed actors
  - Provide actors depending on their context accurate information

- Self-adapting overlays
  - Use physical information to establish a good dissemination infrastructure
  - useful when infrastructure behaves fragile

- Look at coordination mechanisms for actors accessing common objects
  - Event scheduling
    - Consider importance of events
    - Critical application
    - Provide mechanisms that reduce the risk that important events are lost
  - Examine ways of resource managing
What I have to offer: PCache

- A middleware able to store information that may be relevant for multiple nodes in ad hoc/sensor networks
  - Replicates data
    - Availability
    - Query latency
  - Assumes that not all nodes should/can store every data item
  - Cheap
    - In number of messages
    - In memory consumption
- Spreading copies of the data items
- Keeps copies not to close and not to far from each other
- New records are broadcasted to the network
- Decision to cache is based on:
  - Distance of the previous copy
  - Combined with probabilities
How

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PCache Final Distribution
A smart broadcast protocol
- Nodes that retransmit are those that are more far from the source
- Requires less messages than flooding
- Helps PCache to spread the information

Operations

Dissemination
Uses Pampa to broadcast the (key, value) pairs

Query
For a given key, gets the value
- On average replied by nodes 1 or 2 hops away

Gathering
Gets the values whose key satisfies a condition
- Broadcast (PAMPA) with a limited TTL

Data shuffling
- All messages piggyback old records
  - Helps to leverage distribution almost for free
  - Uses probabilities
Applications: SIP

- User location in MANETs
- Extends Simone’s previous work
  - Users register by disseminating a record with personal info
  - Possible queries
    - Who wants to play chess?
    - IP address of Bob?
    - How is Bob reachable (voice, e-mail, chat)?

Does it worth it?

- Comparison with a naïve approach
  - No early dissemination
  - Gains are in number of messages per operation
Other stuff that may be useful

- Fairness in routing
- Anonymity in reputation systems
Space-based Context Queries in Heterogeneous Environments

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My Research

Started with context-aware computing and met ad hoc networks on the way...

Where: heterogeneous environments
  • infrastructure-based + infrastructure-less environments (i.e., mobile ad hoc networks)

What: support context query execution

Why:
  • Enable context-aware applications on resource-constrained mobile devices
  • Enable novel services in ad hoc networks

How: design, implement and evaluate middleware prototypes in testbed of phones
1. Contory

Middleware for context provisioning

Context Query Model

```
SELECT <context type>
FROM <source>
WHERE <predicate clause>
FRESHNESS <time>
DURATION <duration>
EVERY <time>
EVENT <predicate clause>
```

Example:
```
SELECT temperature
FROM adHocNetwork(first3,3)
WHERE accuracy = 0.2
FRESHNESS 30sec
DURATION 1hour
EVENT AVG(temperature)>25
```
Contory Applications

Sailing Application

Weather Watcher

Context-based content provisioning:
DYNAMOS* Prototype Application
2. Migratory Services

To support deployment and execution of services in ad hoc networks

Prototype Migratory Service: TJam

- Predict traffic jams
- TJam uses two types of information that every car owns:
  - number of one-hop neighboring cars
  - speed of one-hop neighboring cars
- Testbed experiments
  - ad hoc mobile network of 11 HP iPAQs with 802.11 cards and GPS
  - 1-2 hops communication
  - 2/3 neighbors
Potential Ideas for the Proposal

- MANET: what did we learn so far? what are the metrics we should consider? what's the best way to evaluate protocols or services in ad hoc networks? when flooding should be preferred to gossip, overlays, etc.?

- Algorithms to support distributed content provisioning in MOBILE ad hoc network
  - Not static sensor networks!

- Vehicular computing applications

- Trust models applied to real systems