

Middleware for Network Eccentric and Mobile Applications
(MiNEMA)

Report from the 3rd MiNEMA Workshop
February 7 - 8 2006
Leuven, Belgium

1st March 2006

Edited by Susana Guedes - MiNEMA Programme Coordinator

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1 Foreword

The aim of the 3rd MiNEMA workshop was to foster further collaboration between existing MiNEMA members, and to advertise and widen participation in the MiNEMA network. Research results were sought both from young and senior researchers in the field. Both reviews of finished work, as well as work in progress on new research were planned to create a dynamic programme which could be the basis for fruitful discussions and new collaborations. Participants were requested to submit research papers, study topics or papers describing the lessons learned with past projects. The submissions were reviewed by a program committee formed by all the members of the MiNEMA SC. The final program included 23 papers. The organizing committee was formed by the following members of the DistriNet, K.U.Leuven: Tom Goovaerts, Wouter Joosen, Bert Lagaisse, and Peter Rigole.

2 Organizing committee

- Tom Goovaerts
- Wouter Joosen
- Bert Lagaisse
- Peter Rigole

3 Program Committee

- Gordon Blair
- Laszlo Boeszoermyi
- Vinny Cahill
- Charalambos D. Charalambous
- Roy Friedman
- Wouter Joosen (PC chair)
- Jorg Kaiser
- Ole Lehrman Madsen
- Kimmo Rattikaainen
- Luis Rodrigues
- Philippas Tsigas
- Benoît Garbinato

4 Program

Monday, February 6, 2006

20:00 - 22:00 Workshop get-together: meet your fellow workshop participants.

Tuesday, February 07, 2006

08:00 - 08:45 Registration and morning coffee

08:45 - 09:00 Welcome

09:00 - 10:00 Session 1: Keynote

- Industry talk

10:00 - 10:20 Coffee Break

10:20 - 12:30 Session 2: Coordination

Research papers (30 min):

- Semi-probabilistic Content-Based Event Dissemination in Dynamic Networks, Costa et al.
- Firefly Synchronization in Ad Hoc Networks, Tyrrell et al.
- Self Describing components in cooperating systems, Pointek et al.

Study topics (20 min):

- Coordinated and Causally aware MANETs, Gidenstam et al.
- Study Topic: Cooperative Storage in Ad hoc Wireless Networks, Gavidia et al.

12:30 - 14:00 Lunch

14:00 - 15:40 Session 3: Services - security and discovery

Research papers (30 min):

- A Lightweight Access Control Mechanism for Linda-based Coordination Systems, Iliasov et al.

Lessons Learned (30 min):

- Service Discovery in Mobile Ad hoc Networks, Mian et al.

Study topics (20 min):

- Distributed Ontologies and Semantic Service Discovery in Mobile Ad Hoc Networks, Nedos et al.
- Protecting Internet Connectivity of Hybrid Ad Hoc Network Gateways, Lindqvist et al.

15:40 - 16:00 Coffee Break

16:00 - 17:20 Session 4: Services - communication

Research papers (30 min):

- On Group Communication, Congestion Avoidance and Fair Medium Access in MANETs, Singh et al.
- Spatio-Temporal Communication primitives for Delay Tolerant Systems, Musolesi et al.

Study topics (20 min):

- Robust Information Transmission and Control Subject to Uncertainty and Capacity Constraints, Charalambous et al.

17:20 - 18:00 Refreshment break.

18:00 - 20:00 Group event.

20:00 Workshop Dinner

Wednesday, February 08, 2006 08:30 - 09:00 Morning coffee

09:00 - 10:40 Session 5: Architecture

Research papers (30 min):

- A Uniform Publish-Subscribe Infrastructure for Communication in Wireless Mobile Environments, Bronsted et al.

Lessons Learned (30 min):

- A Flexible, yet Performant Session Layer Mobility Solution, Mahieu et al.

Study topics (20 min):

- Relying on Wireless Sensor Networks to Enhance the RC-Gaming Experience, Guerrero et al.
- A study topic: Real-time Architecture for Networked Multimedia Streaming systems, Rizvanovic et al.

10:40 - 11:10 Coffee break

11:10 - 12:00 Session 6: Architecture

Research papers (30 min):

- LightPeers A Framework Supporting Nomadic Learning in Mixed Environments with Mobile Ad Hoc Networking, Christensen et al.

Study topics (20 min):

- Contory: A Middleware for Context Provisioning on Mobile Devices, Riva et al.

12:00 - 13:30 Lunch

13:30 - 14:50 Session 7: Adaptation

Research papers (30 min):

- Policy-Driven Adaptation for Protocol Stacks, Rosa et al.
- An adaptive and self-organizing Proxy-to-Proxy Middleware, Spielvogel et al.

Study topics (20 min):

- MiTS: Middleware for Travelling Sensor Nodes, Elen et al.

14:50 - 15:10 Coffee break

15:10 - 16:10 Session 8: Adaptation

Research papers (30 min):

- A Mirror Based Approach to Building Reflective, Adaptive Middleware: Gjorven et al.
- A Configurable Event Notification Service for MANETs, Skjelsvic et al.

16:10 - 16:30 Closing session

5 Abstract of talks

Semi-probabilistic Content-Based Event Dissemination in Dynamic Networks

Costa et al

Abstract

Modern distributed applications exhibit increasing degrees of dynamicity, due to topological reconfigurations occurring at the physical or logical level. Supporting application development through middleware in dynamic scenarios in many cases demands new approaches to routing the applicative information managed by the middleware. Current approaches exploit either a deterministic approach, relying on the dissemination of routing information, or a probabilistic one, inspired by the diffusion of epidemics. However, both have drawbacks. In this paper we describe a semi-probabilistic routing approach targeted to publish-subscribe middleware for highly dynamic networks. Our routing strategy strikes a balance between the two aforementioned approaches, by combining the scalability and resilience to change of probabilistic approaches with the ability to quickly steer events towards the intended receivers typical of deterministic approaches.

Firefly Synchronization in Ad Hoc Networks

Tyrrell et al

Abstract

In this article spontaneous synchronization observed in nature is applied to self-organized wireless networks. In South-East Asia huge swarms of fireflies emit light flashes in perfect synchrony. The underlying principle of this firefly synchronization scheme is reviewed and challenges related to the implementation in ad hoc networks are addressed. In particular, the effects of transmission delays and the constraint that a node cannot receive and transmit at the same time are studied.

Self Describing components in cooperating systems

Pointek et al

Abstract

This paper presents CODES, a scheme to describe the services and properties of smart, networked devices. Interaction between these components is facilitated using the event-based middleware COSMIC, which is particularly designed for small embedded applications. CODES is specifically tailored to provide machine-readable descriptions for COSMIC components. In this paper we will focus on the problems of what kind of information is needed, how the descriptions are stored in a compact form in the tiny devices and the aspect of discovering components, which is particularly important in a dynamic and mobile environment. The descriptions are

tailored for sensor/actuator networks and include basic properties of a component, the events which the component produces or consumes, and the required QoS properties of dissemination which is used by the underlying system to reserve the respective resources. As an appropriate description language, XML has emerged during the last years. XML provides considerable flexibility and ease of post-processing with a wide variety of available tools.

Coordinated and Causally aware MANETs

Gidenstam et al

Abstract

We present work in progress on how to establish dynamic clusters in Mobile Ad-hoc Networks (MANETs). A cluster corresponds to an area of interest and allows at most n processes to access resources associated with the cluster at the same time. Event dissemination algorithms can benefit from clusters in order to control access to resources as well as to maintain the order of disseminated events. In this paper we discuss the issues of managing dynamic clusters in a MANET.

Study Topic: Cooperative Storage in Ad hoc Wireless Networks

Gavidia et al

Abstract

Devices enabled with wireless communication capabilities can potentially create ad hoc networks to support a variety of applications. Cooperation between nodes is at the heart of ad hoc networking, as nodes need the help of their neighbors to route packets to destinations outside of their range. As with routing, nodes in an ad hoc wireless network can benefit from cooperation to overcome other limitations. Dependable and secure data storage is one area where wireless nodes can benefit from collaborating with each other.

Distributed data storage has been addressed in projects such as distributed file systems and digital libraries (LOCKSS [8]). While distributed file systems are mostly concerned with efficient file storage and retrieval, digital libraries focus on persistent archival of the data over long periods of time. Data storage in distributed file systems has been tackled using a client-server model (Coda, Petal) as well as using a peer-to-peer approach (CFS [5], Glacier [6], Farsite [1]). Some of these systems rely on underlying distributed storage mechanisms such as PAST [10], DHASH, Oceanstore [7], FreeNet [4] and FreeHaven. These cooperative storage systems have distinct properties. For example, while systems like FreeNet and FreeHaven are more concerned with providing anonymity for users and discouraging censorship, projects like OceanStore put considerable effort into providing strong persistence. Regardless of the implementation, these systems share the same goal: store data with high guarantees that the data will remain uncorrupted and be available for later retrieval.

Dependable storage requires redundancy to ensure availability of the data. Under perfect conditions, where nodes are not subject to failures and the communication channels remain intact, having only one copy of a data item could suffice. Whenever a user required a copy, he/she could fetch it from the owner/creator of the data item. Even in this ideal scenario, replication could help locate replicas closer to potential users reducing latency. However, in

practice, networks are more likely to have dynamic topologies, which is specially true for wireless networks, and the value of replicating data becomes more apparent. By having several copies of the same data item, node failures or disconnections are less likely to affect the availability of the data, as it could be recovered from another location. Moreover, a user could safely store his/her data at other nodes to ensure that it is secure in case of a catastrophic failure of their computing device.

A Lightweight Access Control Mechanism for Linda-based Coordination Systems

Iliasov et al

Abstract

This paper proposes a simple and lightweight mechanism for data access control in open Linda-based coordination systems. The access control is implemented by dynamically restricting the kind of tuples that an agent can produce, consume and remove. It also includes a One-grained mechanism for delegating rights for access control reconfiguration. The proposed mechanism builds around the Linda tuple matching and can be easily integrated into any Linda-based coordination system. Our analysis shows that this type of access control is easy to implement and it introduces a very little overhead.

Service Discovery in Mobile Ad hoc Networks

Mian et al

Abstract

Service discovery in mobile ad hoc networks (MANETs) is challenging issue. As nodes in a MANET offer spontaneous and variable connectivity, the proximity of a given service as well as the kind of the number of services vary unpredictably with time. Traditional directory based architectural solutions can hardly cope with such a dynamic environment with while a directory-less approach has to resort to network-wide searches. Moreover deploying a service discovery protocol on top of a routing protocol is another source of inefficiency, since similar problems have to address twice by both protocols. In the ongoing work we are trying to tackle the problem of service discovery by leveraging on the random walk based search.

Distributed Ontologies and Semantic Service Discovery in Mobile Ad Hoc Networks

Nedos et al

Abstract

Service discovery in ad hoc networks must cope not only with failureprone mobile nodes, but also with an environment where opportunistic and deeply unpredictable interactions are the norm. The use of ontologies and semantic services can help ameliorate some of these problems by providing a rich infrastructure for service description and discovery through semantic reasoning. However, a single common ontology in each mobile node, is an inappropriate assumption for such a dynamic environment. Multiple independent ontologies are more applicable but pose many technical challenges. In particular, to accurately discover available services when described by independent ontologies, one has to aggregate, match and further disseminate these ontologies. We present here a model to enable semantic service discovery in MANETs. A central part of the model is the distribution of the ontology dissemination and matching tasks amongst the mobile nodes. Using a gossip based protocol for dissemination and a lightweight ontology matching algorithm, the model offers predictable performance and an even distribution of physical resources amongst participating nodes. This makes it suitable for resource constraint, mobile devices. In this short paper we present the motivation and the description of the gossip protocol.

Protecting Internet Connectivity of Hybrid Ad Hoc Network Gateways

Lindqvist et al

Abstract

Denial of Service (DoS) attacks are a real problem in the Internet today. Future mobile all-IP hybrid ad hoc networks can suffer from the same problems as their fixed network counterparts. However, hybrid ad hoc networks are vulnerable even to small scale DoS attacks. In this paper, we present two DoS attacks against Internet connectivity in hybrid ad hoc networks with a single gateway. The attacks can originate from the ad hoc network or from the Internet. We describe well-known ad hoc network routing protocols and how they can be extended to cope with DoS attacks. We discuss how the DoS attacks can be mitigated with the Host Identity Protocol (HIP).

On Group Communication, Congestion Avoidance and Fair Medium Access in MANETs

Singh et al

Abstract

Mobile ad hoc networks (MANETs) are opportunistic networks formed by mobile devices using a wireless medium to communicate with each other. Implementing a reliable communication substrate for MANETs requires mechanisms to handle congestion. Further, MANETs based on IEEE 802.11b MAC protocol suffer from the problem of unfair medium access across nodes, requiring mechanisms to avoid node starvation. Traditionally congestion control has been widely adopted to handle network congestion. In this paper we motivate a congestion avoidance mechanism for MANETs. The motivation for the suggested mechanism is that each node can utilise the knowledge about other nodes in theMANET and those present in their immediate neighbourhoods. The same information can also be used to prevent node starvation.

We show that this information can be easily extracted from a system like TransMAN. TransMAN is a group communication system for MANETs that provides participating nodes with consistent list of all nodes in the network and ordered message delivery. TransMAN reacts to frequent network changes by maintaining a list of transient views and running agreements between nodes for the next view. The transient views provide nodes with knowledge of other nodes that have recently joined the network. The transient views and the group view provide the knowledge based on which nodes can predict congestion or starvation and take measures to avoid it.

Spatio-Temporal Communication primitives for Delay Tolerant Systems

Musolesi et al

Abstract

Computing and communication devices pervasively surround our daily life and the presence of embedded systems, including tiny sensors, is increasing exponentially. However, the software and communication mechanisms used to network these devices are still the ones that we have been devised 30 years ago for standard computer systems. Different communication and coordination patterns are emerging for these environments, ranging from those related to delay tolerant systems [3], where communication happens asynchronously between devices, to location based communication, where hosts receive information only when they are in a specific location. In these environments, several concepts, not captured by the semantics of the programming interfaces of traditional systems, such as location or temporal validity of the disseminated and replicated information, are fundamental.

In this paper we propose a novel set of communication primitives for this kind of systems that would allow developers to better exploit the potential of these environments. These primitives combine spatial and temporal concerns to cope with the dynamics and mobility of pervasive systems. We also discuss a middleware framework that implements the proposed programming interface.

Robust Information Transmission and Control Subject to Uncertainty and Capacity Constraints

Charalambous et al

Abstract

In a view of newly emerged technologies (e.g. sensor networks), where communications and control meet one another, it is of practical and theoretical interest to consider communication-control problems in a unified setting. The goal of this paper is to address the problem of robust information transmission and control, when the underlying systems are stochastic, uncertain, and subject to power constraints. The paper addresses specific research areas and proposes the concepts, which could be useful in the analysis and design of robust transmission and control systems. The emphasis is on: 1) Developing the subject of robust information theory, in which the Shannon blocks of communication systems, such as sources, channels, and source and

channel encoders and decoders, are subject to uncertainty and power constraints; 2) Enhancing the knowledge in dealing with uncertainty when the systems are governed by nonlinear stochastic differential equations using information theoretic concepts, such as relative entropy, free energy, and the Cramer transform of Large Deviations theory; 3) Studying the stabilizability of control systems under communication constraints using information theoretic concepts, such as channel capacity and entropy rate.

A Uniform Publish-Subscribe Infrastructure for Communication in Wireless Mobile Environments

Bronsted et al

Abstract

An important part of any distributed system is the middleware. The middleware should present a clean and understandable abstraction over communication to the application programmer and hide the complexity of low level network programming. It has previously been shown that the publishsubscribe messaging paradigm provides a good communication abstraction for wireless networks of mobile nodes. In this paper we present PSI, a uniform publish-subscribe based infrastructure, for communication in wireless mobile environments. In PSI the application is divided into software components that each handles a well defined part of the functionality and communicate with other components using the publish-subscribe paradigm. From a components perspective it makes no difference where the receivers of a messages are located - in the same process, in another process on the same node, or in a process on remote node. All communication is handled uniformly. By showing how the infrastructure is used in a concrete instance we argue that it meets the requirements for middleware stated above and provides a good programming model for distributed systems in mobile environments.

A Flexible, yet Performant Session Layer Mobility Solution

Mahieu et al

Abstract

Current day mobility solutions in the protocol stack lack a number of characteristics that result in the suboptimal functioning of communication software. This paper proposes 4 properties that mobility solutions must possess to address these restrictions: application cooperation, higher layer mobility awareness, general applicability and protocol heterogeneity. Subsequently, a mobility solution that realizes all these properties is described. The solution introduces a session layer in the protocol stack that consists of two subsystems: the connection abstraction system and the address management system. First measurements show that the overhead of this solution amounts to approximately 10% Other mobility solutions found in the literature, session layer and others, typically only realize a subset of the four properties. This paper is mainly based on [7].

Relying on Wireless Sensor Networks to Enhance the RC-Gaming Experience

Guerrero et al

Abstract

Maturity of wireless sensor networks will lead to a world full of smart objects, and remote controlled toys are no exception. Following the growing popularity of multiplayer computer games, we envision a novel application that enriches the gaming experience by taking the digital multiplayer interaction into the physical world of remote controlled toys. We propose the development of an infrastructure that relies on wireless sensor networks as the glue that makes it possible that remote controlled toys can be used in multiplayer games, and provide a roadmap for the development of such an infrastructure.

A study topic: Real-time Architecture for Networked Multimedia Streaming systems

Rizvanovic et al

Abstract

The work presented here has started as part of a FABRIC EU IST project. The aim of the FABRIC project was to develop an architecture in which several interoperability standards and technologies in the home networking context can be integrated. In addition, the FABRIC aimed to handle the complete network to satisfy End-to-End Quality of service (QoS) requirements. In this paper we propose an adaptive QoS framework for efficient resource management, called the Matrix approach. The Matrix is a concept to abstract from having detailed technical data at the middleware interface. In stead of having technical data referring to QoS parameters like: bandwidth, latency and delay we only have discrete portions that refer to levels of quality. The underlying middleware must interpret these values and map them on technical relevant QoS parameters.

LightPeers A Framework Supporting Nomadic Learning in Mixed Environments with Mobile Ad Hoc Networking

Christensen et al

Abstract

This paper describes the LightPeer framework, which is a generic P2P framework inspired from work with school children who could benefit from a P2P based infrastructure in their project oriented field work. The focus for developing the LightPeers framework has been on the following set of objectives: to define a lightweight framework, that can run on devices with limited resources, introduce the use of a community tagging mechanism as a means for loosely describing applications and resources, and finally to extract the notion of shared sensors in a dedicated logical framework layer.

Contory: A Middleware for Context Provisioning on Mobile Devices

Riva et al

Abstract

In an effort to support effective deployment of context-aware applications on mobile devices (and in particular mobile phones), we propose Contory, a middleware specifically deployed to support context provisioning on mobile devices. Contory integrates three different mechanisms for context provisioning: sensors-based provisioning, centralized context infrastructure, distributed context infrastructure in ad hoc networks. By means of a simple and intuitive declarative query language, context-aware applications can request and collect context information provided by the middleware. This language features on-demand, periodic, and event-based context queries. The advantage of our approach is that mobile devices do not need to always rely on the presence of a service infrastructure or to be always equipped with all the necessary sensors to acquire the desired context information.

Policy-Driven Adaptation for Protocol Stacks

Rosa et al

Abstract

Today's mobile applications need to be designed to execute in a wide range of heterogeneous devices which operate in different conditions. In this context, dynamic adaptation of the underlying communication support is fundamental to achieve adequate performance. This paper addresses the problem of supporting dynamic adaptation of communication protocol stacks.

When the adaptation code is entangled with the protocol code it may become hard or even impossible to reason about the adaptation logic, reuse it in different contexts, and tune it in runtime. Therefore, we propose a policy driven approach for runtime adaptation of protocol stacks, where the adaptation logic is described through high-level policies, decoupled from the protocol logic. In this paper, we concentrate on the policy language and modeling primitives to explicitly capturing the common adaptation requirements that were identified after more than five years of experience with the Appia framework.

An adaptive and self-organizing Proxy-to-Proxy Middleware

Spielvogel et al

Abstract

State-of-the art of content distribution including continuous data is via:

- Traditional Client/Server Architectures
- Peer-to-Peer (P2P) computing Frameworks
- Content Delivery Networks (CDNs).

Client/Server Architectures do not scale well. Moreover, if the connection between the client and the server has not the necessary level of QoS then video streaming may be impossible, even if the server is far from being overloaded. P2P communication [7] [4] [5] has good features for data transmission with limited requirements, but it is too much fragile to serve as a basis for video streaming. CDNs [11], [6] are rigid, static, proprietary and expensive.

We suggest an intermediate solution, based on dynamic overlay networks of proxies. We call this technology X2X Streaming (streaming based on proxy-to-proxy communication). The basic idea is that content, typically but not necessarily originating from large, high-quality servers and from live broadcast sources, is dynamically replicated (fully or partially) onto logical networks of proxies supporting a small geographic region and a certain area of interests. For example, a network of proxies of hotels in one area, another network of proxies of basket ball clubs in another area may build such proxy groups. Such groups share besides computing and networking resources also access rights and get thus an inexpensive and extremely efficient streaming service.

MiTS: Middleware for Travelling Sensor Nodes

Elen et al

Abstract

In this paper, we consider a sensor network application as a composition of environments (physical and optionally logical clusters of sensor nodes) that each have a relatively static topology and sensor nodes that migrate through these environments. We call the latter travelling sensor nodes.

We illustrate why travelling sensor nodes are needed in many challenging sensor node applications. We sketch the requirements for the system software of these travelling sensor nodes and we outline our approach to architecting an adaptive middleware layer for such sensor nodes.

This paper reports on a starting project in which we start from the observation that the current operating system and virtual machines for sensor nodes do not contain all the needed support for highly mobile nodes. A specific middleware solution therefore is required. We mainly present a first inventory of the requirements and a highlevel architecture of such middleware.

A Mirror Based Approach to Building Reflective, Adaptive Middleware

Gjorven et al

Abstract

Systems are increasingly expected to adapt themselves to changing requirements and environments. Recent works use a middleware-based approach to selfadaptivity where the adaptation mechanisms and metalevel information are separated and externalized from the application code. Current solutions handle the individual phases of the service lifetime separately and independently leading to a need for managing synchronization between several meta-level information models. In this paper we propose an adaptive middleware that provides mirror-based reflection. Mirror-based reflection supports reflection on an application, or any service,

through all the phases of its lifecycle, including pre-runtime, using one uniform model. This sophisticated form of reflection contributes to the realization of a comprehensive adaptation methodology that facilitates the development of a wide range of adaptive behaviors.

A Configurable Event Notification Service for MANETs

Skjelsvic et al

Abstract

In the Ad-Hoc Infoware project, we design middleware services for emergency and rescue scenarios in mobile Ad-Hoc Networks (MANETs). One of these services is a Distributed Event Notification Service (DENS) for asynchronous communication. Different scenarios, characterized by parameters such as node density and the degree of mobility may benefit from using different protocols for sending out notifications to subscribers. In this paper, we present our DENS protocols and discuss challenges in how to do the configuration of the DENS before and during the rescue operation.