P2P, Ad Hoc and Sensor Networks – All the Different or All the Same?

Working Group Summary

Peter A. Boncz
CWI - Amsterdam
P.Boncz@cwi.nl

Angela Bonifati
ICAR - CNR - Rende
bonifati@icar.cnr.it

Joos-Hendrik Böse
FU Berlin
boese@mi.fu-berlin.de

Stefan Böttcher
Universität Paderborn
stb@upb.de

Panos Kypros Chrysanthis
University of Pittsburgh
panos@cs.pitt.edu

Le Gruenwald
US National Science Foundation
ggruenwald@ou.edu

Arantza Illarramendi
Universidad del Pas Vasco
jipileca@si.ehu.es

Peter Janacik (Working Group Chair)
Universität Paderborn
pjanacik@upb.de

Birgitta König-Ries
Universität Jena
koenig@informatik.uni-jena.de

Wolfgang May
Universitt Göttingen
may@informatik.uni-goettingen.de

Anirban Mondal
University of Tokyo
anirban@tkl.iis.u-tokyo.ac.jp

Sebastian Obermeier
Universität Paderborn
so@upb.de

Aris Ouksel
University of Illinois at Chicago
aris@uic.edu

George Samaras
University of Cyprus
cssamara@cs.ucy.ac.cy

Brahmananda Sapkota
DERI, Nat. Univ. of Ireland, Galway
brahmananda.sapkota@deri.org

Rita Steinmetz
Universität Paderborn
rst@uni-paderborn.de

Stratis D. Viglas
University of Edinburgh
sviglas@inf.ed.ac.uk

Summary. Currently, data management technologies are in the process of finding their way into evolving networks, i.e. P2P, ad hoc and wireless sensor networks. We examine the properties, differences and commonalities of the different types of evolving networks, in order to enable the development of adequate technologies

Dagstuhl Seminar Proceedings 06431
Scalable Data Management in Evolving Networks
http://drops.dagstuhl.de/opus/volltexte/2007/951

suiting their characteristics. We start with presenting definitions for the different network types, before arranging them in a network hierarchy, to gain a clear view of the area. Then, we analyze and compare the example applications for each of the types using different design dimensions. Based on this work, we finally present a comparison of P2P, ad hoc and wireless sensor networks.

1 Introduction

During the past decade, data management technologies for wired environments have reached maturity. They have been successfully applied by industry as essential constituents of many products and applications. In contrast to wired networks, evolving networks are still uncharted terrain for data management technologies. The Dagstuhl working group, consisting of the authors of this paper, decided to explore this new terrain in order to establish a better understanding of the different types of evolving networks.

Evolving networks subdivide into peer-to-peer, mobile ad hoc and wireless sensor networks. In order to get a clearer view of these network types, we chose to discuss their similarities and their differences. We start by collecting definitions and further subdividing these types where applicable. Using these definitions, we derive a hierarchy of networks (Section 2). Our aim is to answer the question: what are the similarities and differences concerning data management? To achieve this, we compare typical applications from each of the network types using common design dimensions that we defined in advance (Section 3). Finally, we present a conclusion in Section 4.

2 Definitions

Summarizing the discussion of diverse understandings of the different network types, we present the following definitions:

Mobile Ad Hoc Networks: A mobile ad hoc network (MANET) is a kind of wireless ad hoc network, and is a *self-configuring* network of mobile routers (and associated hosts) connected by wireless links—the union of which forms an *arbitrary* topology. The routers are *free to move randomly* and organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably (inspired by [1]). Alternatively, a MANET may be considered as a mobile version of an ad hoc network.

Wireless Sensor Network: A wireless sensor network (WSN) is a wireless computer network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations (inspired by [2])

Mobile Wireless Sensor Network: A wireless sensor network in which the nodes are mobile.

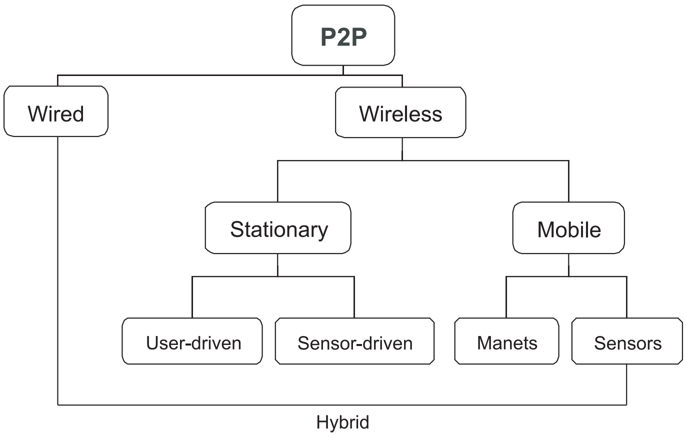

Fig. 1. Hierarchy of network types

Ad Hoc Wireless Sensor Network: A wireless sensor network in which the nodes self-organize.
P2P Network: A network without the notion of clients or servers, but only equal peer nodes that simultaneously function as both *clients* and *servers* (inspired by [3]).

The above networks are arranged in the hierarchy depicted in Figure 1. In the figure, there is an additional link between wired networks and mobile sensors referring to the hybrid networks composed of these two network types. Moreover, both stationary and mobile wireless networks are further distinguished into user- and sensor-driven types.

3 Data Management Applications

In order to enable a more structured examination of typical applications for P2P, ad hoc and wireless sensor networks, we define the following list of design dimensions covering different aspects:

- *Data modeling*
- *Query processing*
- *Transactional control*
- *Information discovery*
- *Information dissemination*
- *Data placement*
- *Data availability/reliability*
- *Data persistence*
- *Data security*

- *Timeliness*

The applications described in the following subsections are chosen since they are typical for their network types. They are examined using the above design dimensions.

3.1 WSN Application: Environmental Monitoring

Environmental monitoring is one of the classical applications for wireless sensor networks. One example for environmental monitoring is vineyard monitoring, described in [4]. In the system, data is collected from a vineyard and interpreted thereafter to issue recommendations according to the vineyards state. After studying vineyards as a potential test site, the authors deployed eighteen wireless sensor network nodes in an Oregon vineyard for several weeks. They point out that the nodes deployed can be equipped with temperature, lighting, humidity, and movement sensors, thus being able to provide the vineyard managers with suggestions for a tangible next step. This way, the system is planned to be able to issue frost warnings, calculations of mildew risk for individual parts of the vineyard, and even harvest time recommendations. We analyze the application of environmental monitoring using the established design dimensions:

- *Data modeling*: Data is typically modeled in records of sensor measurements.
- *Query processing*: Most queries in this network are continuous and multiple queries may be executed at the same time. Data is aggregated in the network in order to reduce communication costs. There are also applications in which data can be streamed.
- *Transactional control*: Not used in this application class.
- *Information discovery*: In this class of applications, there is an interest in abnormal conditions, e.g. unusually high temperature values. Therefore, information discovery protocols have to be designed to focus on this interest.
- *Information dissemination*: Set up or operation status information are the major information types disseminated.
- *Data placement*: Data placement is used to implement in-network data aggregation. Further, data is stored within the network in adequate structures.
- *Data availability/reliability*: Given frequent network failures, there has to be a management of corrupted or missing data. Fault tolerance is achieved through aggregation, estimation and redundancy.
- *Data persistence*: Persistence is used in the context of storing summarized information within the network.
- *Data security*: Data has to be protected especially against tampering.
- *Timeliness*: Timeliness of data is an important aspect, since late information is usually of lower value.

3.2 Manet Application: Disaster Recovery

In cases of disasters, the existing infrastructure is often damaged or destroyed. Natural disasters e.g. lead to the loss of electricity and Internet connectivity, as described in [1]. An ad hoc network can be used to overcome the problems incurred by missing infrastructure, helping to better cope with the consequences of such calamities. Mobile units may carry networking equipment to support routing operations. This way, e.g. mobile police and firefighter units are enabled to exchange and share information. We analyze the application of disaster recovery using the established design dimensions:

- *Data modeling*: Models of resources and workflow data.
- *Query processing*: Most of the queries are created in ad hoc manner or are queries triggering some action (i.e. triggers).
- *Transactional control*: The semantics used are application dependent.
- *Information discovery/dissemination*: The design of protocols has to consider the context of system components and nodes. Given heterogeneous platforms, cross-system data integration is necessary.
- *Data placement*: Not relevant in this scenario.
- *Data availability/reliability*: Data can be made available using some form of controlled flooding. Protocols have to be robust (e.g. employing multilevel redundancy) and context-driven (e.g. utilizing priority control).
- *Data persistence*: In most cases, weak persistence is important for accounting. It is realized according to the role of a particular component or part of the system.
- *Data security*: A contingency-driven security mechanism is used.
- *Timeliness*: The system as a whole has to exhibit responsiveness using a context-driven protocol design.

3.3 P2P Application: Multiplayer Games

Many of today's multiplayer computer games need to support a large number of online players simultaneously. In such games, thousands of players move around in a virtual, persistent world, interacting with each other and their environment. Eve online, for example, a massively multiplayer online game experiences over 150 million database transactions per day [5]. Multiplayer games will need to be based on P2P architectures, in order to work under high load that can be expected to be even much higher in the future, overcome scalability limitations and avoid single points of failure. We analyze the application of multiplayer games using the established design dimensions:

- *Data modeling*: The game world and the player's actions have to be modeled.
- *Query processing*: Most queries are issued during initialization and setup situations, but also, for obtaining information about the state of an entity during the game.

- *Transactional control*: Transactional control is used for the coordination of actions, e.g. buying or selling items.
- *Information discovery/dissemination*: State information is discovered/disseminated in order to enable interactions based on this information between different entities. In many games, objects e.g. have to be advertised.
- *Data placement*: Data is placed in distributed data structures, such as hash tables.
- *Data availability/reliability*: Data availability/reliability depends on the specific game requirements.
- *Data persistence*: In order to implement accounting, persistence is needed. The implementation of persistence depends on the underlying infrastructure.
- *Data security*: Security depends on the specific application and is often important for accounting.
- *Timeliness*: Deadlines in the system have to be met in order to enable users to play the game in an interactive way.

3.4 Comparison

Looking at the different applications, many commonalities become evident: The use of overlay structures, e.g. data aggregation trees in the wireless sensor network and distributed hash tables in P2P networks connecting internet applications. Further, all of the considered networks work without central control and do not require a coordinator or server connecting and coordinating the participants' activities.

On the other hand, there are several differences between the discussed network types. They not only become apparent when examining and comparing the application examples, but also when traversing the network hierarchy tree depicted in Figure 1.

4 Conclusion

The objective of this paper is to answer the question: P2P, ad hoc and wireless sensor networks—are they all the different or all the same? In order to get a clearer view of the relationship between these networks, the paper defines the corresponding terms and presents a hierarchy of network types. Further, it analyzes the similarities and differences of P2P, ad hoc and sensor networks by comparing typical applications for the networks using a set of common design dimensions.

Examining the compared applications and the established network hierarchy, it becomes apparent that the different network types share several common properties. Key commonalities are that all of the networks are connected using overlay structures, like routing trees and hash tables. Further, all of them do without central control. On the other hand, there are some major differences reflecting the different requirements of the applications, which also become evident when traversing the network hierarchy tree.

References

1. Charles E. Perkins. *Ad Hoc Networking*. Addison-Wesley, Boston, MA, first edition, 2001.
2. K. Römer and F. Mattern. The design space of wireless sensor networks. *IEEE Wireless Communications*, 11(6):54–61, 2004.
3. G. Fox. Peer-to-peer networks. *IEEE Computing in Science & Engineering*, 3(3):75–77, 2001.
4. Jenna Burrell, Tim Brooke, and Richard Beckwith. Vineyard computing: Sensor networks in agricultural production. *IEEE Pervasive Computing Magazine*, 3(1), 2004.
5. Eve Online Press Releases. Eve online launches largest supercomputer in the gaming industry running on ibm server technology. Online. http://www.eve-online.com/pressreleases/default.asp?pressReleaseID=25, accessed January 23, 2007.