Abstract

Access to information is vital for today’s and tomorrow’s distributed applications, regardless of location, time, and computation environment. In the wired Internet, peer-to-peer communication has had a great impact how information is shared. Now, when the world constantly is becoming more and more mobile there is a need to apply the same functionalities in this domain as well. Wired network technologies are based on assumptions like that the nodes have a fixed place and thus non-mobile. Now, when suddenly we have mobile nodes in the network we will get a dynamic network, called Mobile Ad-hoc Network (MANET), which present new challenges from the network management point of view. In addition to the mobility issues, the mobile devices have much less resources than the nodes in a fixed network, so this also will introduce problems to be solved. P2P in MANETs have received a lot of attention from researchers trying to solve the new problems we face when compining these two technologies. In this paper, we will present and discuss how JXTA and JMS are used in MANETs.

KEYWORDS: Mobile P2P, MANET, Ad-hoc, Information sharing, JXTA, JMS.

1 Introduction

Due to the recent explosive expansion of the mobile device marketplace, and the development of better and cheaper wireless mobile devices we are now facing a migration of the wired Internet with the wireless world. This introduces new problems due to the characteristics and limitations of the wireless domain. Differences in processing power, battery life, bandwidth, and input and output possibilities are examples of the most critical areas where we face problems, which must be overcome. Today’s research in the wireless domain is quite extensive and the progress has been good on several fronts.

One of the most interesting topics when discussing communication nowadays is peer-to-peer communication and information sharing using this technology. P2P (P2P) has replaced the client-server architecture in many areas and the prospects are that it will be implemented in even more areas in the future. Benefits such as load balancing, dynamic information repositories, redundancy, and fault tolerance make it superior to the old client-server communication model in many ways. In addition, one of the greatest drivers in the wired environment has been, and still is, the possibility to share (copyright protected) media over Internet in a very easy and effective way. Other important issues are IM (Instant Messaging) and VoIP (Voice over Internet Protocol). Together these make such an immense driving force that the whole Internet’s development has been riding its wave.

Now when wireless devices and the Internet are constantly coming closer to each other, we will soon have the big drivers and enablers for using P2P in a wireless environment too. The demand for P2P in MANETs [1] is already there: information is needed when making decisions - the more and better information you have, the better will the decision be. This is why mobile nodes also need to have a mechanism for sharing information in a good and effective way. A good example is the future battlespace, which could consist of intelligent machines all connected to a network sharing information about their perceptions. This cooperation would enable instant information availability, which in turn will lead to superiority in warfare. Going from the extreme P2P to a more everyday example, imagine being able to share your ring tones, background pictures et cetera when travelling to work. Yet another example would be if MP3-players would have an interface for searching and downloading music. There are numerous possible application cases for P2P systems.

The remainder of the paper is organized as follows: the wireless environment and a couple of P2P scenarios are presented in section 2. An overview of the JXTA [13] and JMS [14] specifications, and, two P2P systems extending JXTA and JMS to work in a MANET, will be presented in section 3. Security in mobile P2P is briefly discussed in section 4. General discussion about mobile P2P, implementations, and future prospects is handled in section 5. Finally, conclusions are drawn in section 6.

2 Wireless Ad-hoc Environments

When there are no fixed structures in a communicating network all the peers need to route the traffic themselves - you cannot rely on any central entity, which connects you to the rest of the peers. These networks are typically called multi-hop, which means that the traffic goes through multiple other peers in the network before it can be received by the original target. This is of course true in wired networks as well, here you usually do not have a problem with capacity and one important issue is that the network nodes are not considered equal - some are for example dedicated routers.

In some environments it is often not possible to start building the required infrastructure for communication, however, there is still a need to be able to communicate and share in-
information. These environments are often quite small and not permanent as the peers move and join and leave the network at will. On the other hand, there are other bigger networks made up of for example mobile phones, which could be seen as permanent networks even if the individual nodes might move and not return to the same position.

A common factor for all networks is information sharing and in a mobile ad-hoc network it is not an exception. Nodes want to share information with the other nodes and they want to be able to utilize the information others share. Information sharing in MANETs using P2P technology use cases are presented in the following sections.

2.1 Real Life Examples

In this section three examples where the P2P information sharing in a MANET would make sense are presented. Basically, any scenario where someone would benefit from instant information, offered by someone else also benefitting from the system, could implemented P2P.

2.2 Future Battlespace

In a future battlespace it is thought that all vehicles and soldiers would be peers in a information sharing network. These peers would then cooperate and share their perceptions of the battlespace with all other peers. You could resemble it with a network of sensors informing others of their perceptions, so everyone can use the information instantly. In the paper [4] Gagnes describes the utilization of P2P technology in warfare, due to the advantageous characteristics it has.

The army always relies on information about their enemy in order to know how to react - the more information available the better will the decision be. To make this possible for all participating entities need to be able to share and take part of the information. In [3] Larry Williams and Allen H. Kupetz talk about the new 4G communication in warfare and what would be needed by the army. The bottom line is to deliver a system for instant communication with very high quality under extreme circumstances. This is maybe the worst case scenario what would be needed from the network. In this context security will prove to be very critical, because hostile forces cannot under any circumstances gain access to the shared information.

This is the most extreme scenario where P2P could be implemented in a MANET and the requirements for the network are quite extraordinary.

2.3 Emergency Personnel and the Police

Emergency personnel and the police are often confronted with scenarios where instantaneous communication is required in order to organize a rescuing mission or some other task they are confronted with. This would also be a good place to apply this type of technology. All the involved parties can easily exchange all required information and this way ease up the work they are doing. In Finland the authorities are using VIRVE [5], which is a country-wide communication network used by the police and other parties. VIRVE has network infrastructure to support the communication, but instead it could use peer-to-peer technology enabled for MANETs.

2.4 MP3-players

MP3-players are soon as common as mobile phones, so creating a music sharing network with P2P as the underlying technology for these would have good possibilities to be a success. Instead of downloading music from the music company’s website you would just share the music you have, so others in the same MANET can download. This would in the same time give you access to music shared by others. It is important to note that copyright protected music is illegal to share, so other persons can download it. However, this kind of music has been the real driving force on the wired Internet for P2P information sharing, and you could assume the same would apply for P2P in MANETs as well.

2.5 Other Ad-hoc Networks

The possibilities to share information with this kind of technology are almost infinite. Information is everywhere and everybody and everything needs it, so therefore it is easy to come up with a scenario where it could be implemented. To mention a few more use cases for peer-to-peer in MANETs, imagine students in a classroom sharing pictures, ringtones, messages and other files. The students would be a small network cooperating in the traffic routing and this way sharing the information they want.

Another example, taking a bigger scale, could be a network connecting all mobile phones into a MANET. There would be no network infrastructure, so the mobile phones would need to handle all routing by themselves. This would of course require a lot more resources, like battery lifetime, computation power, and bandwidth, from the mobile phones.

Taxis or busses could use this kind of technology to share information about waiting customers and routes they want to take. This could maybe optimize the usage of busses and taxis.

The places to apply this type of technology are many. There is still quite a long way to go before we can start saying we have a complete well-working system. Nonetheless, in the following section we will present two systems enabling peer-to-peer functionalities in a MANET.

3 P2P Implementations for MANETs

Peer-to-peer implementations for MANETs are still more or less on the drawing board. In the following sections we will present two implementations: an extended JMS implementation [2], and an extended JXTA implementation [8], which enable basic P2P technology for MANETs.

3.1 Java Message Service (JMS)

Java Message Service [14] is developed by Sun Microsystems and it is essentially an API providing a common way
for Java applications to create, send, receive, and read messages.

It supports both message queueing and publish-subscribe styles of enterprise-messaging models. Message queueing is briefly a technique where participants communicate through a message queue. This message queue is just a placeholder for messages sent to it waiting to be received. This way of sending messages is one-to-one delivery semantics. Publish-subscribe on the other hand adds the support for one-to-many delivery semantics through the use of topics. A topic can be seen as a mailing list clients can subscribe to and messages sent to it will be distributed to all its subscribers. The topics can be registered and looked-up using Java Naming and Directory Interface (JNDI) [7]. Tables 1, 2 and 3 show the interfaces for developing JMS applications.

JMS supports both persistent and non-persistent message delivery modes, meaning best-effort and guaranteed delivery of messages. The specification does not define how the messages are transported, called the JMS Provider, so this is up to the specific implementation to define.

The characteristics JMS have are interesting when compared to the requirements of a peer-to-peer system. JMS is a message-oriented middleware (MOM) and it is one of the most widely known. MOM is popular, scalable, flexible, and closely coupled with mobile and wireless architectures. All this makes it an interesting choice when trying to deliver peer-to-peer for mobile ad-hoc networks.

In [2] Einar Vollet et al. present a JMS Provider implementation enabling non-persistent JMS topic semantics for MANETs. Due to JMS not being implemented for networks without infrastructure problems arise when trying to use it in this new environment. The following problems have been identified in [2] and should be solved in order to get a completely working peer-to-peer solution for MANETs:

- Configuration, which means the mechanism for discovering the available queues and topics,
- Message transportation, which means the way the messages are transported from one peer to another. In a MANET we cannot rely on a central server to deliver the messages to the right destination,
- Reliability, which means the guarantee that a message will be delivered to the recipient,
- Coordination, which means the mechanism for selecting the receiver of a message if there are multiple recipients associated with a queue.

All four items have not been solved in the paper [2], only the first and the second have been addressed, in the proof-of-concept implementation presented. The reason for this is that number one and two in the list are the most critical ones in order to get the basic P2P technology working.

Addressing the first issue, configuration, means specifying where the queues and topics are located and how the clients can find out about them. The solution taken in [2] was done by adding a local copy of an identical configuration file in each client. This file contains all information required to look-up and use the queues and topics.

The second issue, transportation, requires a multi-hop multicast routing protocol. There are no such routing protocol implemented in the network layer on typical mobile devices, so the approach taken in [2] was to add this routing protocol to the application layer. As the goal of the JMS Provider implementation in [2] was to enable topic semantics for the messaging model multicasting will resemble this quite much. Multicasting is basically a technology to send packets (messages) to a multicast group (topic).

By providing these two extensions to the initial JMS is is possible to successfully create, send, receive, and read messages in a mobile ad-hoc environment. A real P2P solution was tested, as a proof-of-concept, with this extension of JMS in [2].

Another approach, also using JMS to implement a peer-to-peer system for MANETs, has been taken by Mirco Musilesi et al. in [6]. Using epidemic routing the messages are delivered to the destinations, which means that the message will be replicated on each host throughout the network spreading like a virus. Each host maintains a buffer, or a list, of messages it has received. Messages stay in the buffer until they have been acknowledged or the set timeout expires. The acknowledgement will spread through the network too and thus the message will be deleted from each host. Nodes exchange the messages they have with neighbouring nodes, so all nodes have the same messages.

JMS does not provide security for message privacy, this is expected to be provided by the JMS Provider. One way to add security is to enable it in another layer by tunneling the traffic through a secure channel.
An asynchronous communication model is very useful to be used in mobile ad-hoc environments, because the nodes can then receive messages when it is suitable. JMS only provides the asynchronous messaging model, but extending the transportation provider to enable routing in MANETs will deliver a working peer-to-peer system for MANETs.

3.2 JXTA

JXTA [13] (pronounced: juxta) was originally created and developed by Sun Microsystems. Nowadays it is Open Source and the number of participating software developers grows steadily. The main target for JXTA is to offer something P2P systems can be built on top of in order to make them compatible. This something should be:

- interoperable,
- platform independent,
- ubiquitous.

Because JXTA is a set of protocols, specifying basic peer-to-peer functionalities, it can easier reach the goals mentioned in the list above. It is like with TCP/IP. JXTA can be used by any P2P system, in any environment (programming language, operating system and network technology), and, by any device with a digital heartbeat. It contains the very basic functionalities found in a P2P network and all systems implementing the JXTA framework would in theory be compatible. All this is the result of the research work Project JXTA conducted in the beginning [13]. The research results showed that all P2P systems have a similar structure and basic functionalities, and thus the implementations need not be unique and incompatible.

The structure they decided to use was to have JXTA divided into three layers (see fig.1), starting from the top: JXTA Applications, JXTA Services, and JXTA Core [12]. The lowest layer deals with peer establishment, communication management such as routing. The middle layer handles the services used by higher level applications. Examples of these are indexing, searching and file sharing. The top layer is for the applications using the JXTA framework. The layering tries to be as thin as possible and not put constraints on the systems implementing it, rather make room for innovations.

The collection of protocols, which make up JXTA consist of the following:

- Peer Discovery Protocol, is used for publishing and discovering resource advertisements,
- Peer Resolver Protocol, is used to send a generic query to one or multiple peers and getting response to the query,
- Peer Information Protocol, is used to get information about other peers,
- Rendezvous Protocol, is used to propage a message within a peer group,
- Pipe Binding Protocol, is used to establish a pipe between peers (virtual channel),
- Endpoint Routing Protocol, is used to discover the route to an endpoint peer [13].

The general structure of a peer-to-peer network (see fig.2), implementing the JXTA protocol suite, consists of peers ordered into peer groups, which is the virtual world the peers live in. This world is a place where the peers can publish their services to be used by the other peers, however, JXTA does not specify any of this - it just enables the discovery of the services. The services can be available by one peer only or by the whole peer group, so that in case one or more peers fail the service is still available.

All network resources, like the peers, peer groups, pipes and services are represented by advertisements. These uniquely represents an entity in the network.

A peer is an entity, which can speak the protocols in the JXTA network. However, the peer does not have to speak all the protocols in order to be able to use services. A peer is a device capable of computation or just a process in such a device.

A peer group is a collection of peers, which speak the protocols of the peer group.

Pipes are used to abstract the communication channels between services and applications. A pipe is seen by the peer as a direct communication channel to another peer, even if it
in fact goes via several other peers.

In [8] Mario Bisignano et al. present a peer-to-peer system, for a MANET, implementing the JXTA framework. The approach is to add a new layer on top of JXTA, which will address the issues found in MANETs not found in the JXTA framework. In addition to this, changes have been made to the JXTA Core and a couple of new services have been added to JXTA Services layer.

The new middleware solution introduces the following enhancements: management of the intermittent connections and multiple physical interfaces, better resource discovery, and code mobility [8]. This new design offers an API, which can be used by application developers when implementing P2P solutions for MANETs.

The extension made to the JXTA Core layer consists of transportation using multiple physical interfaces. This issue has been solved by extending the EndPoint structure in JXTA. A new module manages the interfaces and provides access to these from the upper layers. The JXTA Services layer has also an extension handling multiple addresses derived from using multiple physical interfaces. In addition, the service discovery mechanism has been added here as well to deal with the highly dynamic features of MANETs. In the original JXTA implementation resources discovered are stored as an advertisement together with a lifetime in a cache. However, the lifetime cannot be specified by the applications, so this has been altered in order to be able to reduce the lifetime of an advertisement. This will better support the dynamic of mobile ad-hoc networks. The final addition to the JXTA framework is the Code Mobility service, which enables peers to upload/download service to/from other peers. It results in better accessibility of a service, because it no longer relies on just one peer in the network. All these enhancements can be accessed through an API provided by the Engine in the application layer.

Furthermore, a meeting scheduler application was been deployed using this extended JXTA framework [8] and it successfully worked in the test environment. However, in a real and more dynamic network than the test environment there could arise new challenges and problems.

Securing JXTA is mainly done by applying known protocols fixing the insecure aspects of JXTA. This approach is basically the same as with JMS.

The goal of JXTA is to deliver a P2P specification, which can be used as a foundation when developing P2P systems. This will make all P2P systems compatible and thus create P2P networks containing many different services that can be used regardless device and environment. JXTA only delivers ways to connect to other peers, find other peers, and, publish and discover services in a network.

4 Security

MANETs are often vulnerable to security attacks due to features like: open medium, dynamic topology, and lack of centralized monitoring and management. The defence line is not very clear. Old ways to protect the networks like firewalls and encryption are no longer sufficient, so there is a great need to come up with new defensive schemes. A centralized authentication infrastructure, for example PKI, is very difficult to apply due to the dynamic nature of the network. Intrusion Detections Systems (IDS) are also extremely difficult to implement in a MANET due to the network characteristics, which in turn might blur the view what is a hostile node and what is a node temporarily having incorrect information. Routing is also a part of the network, which is very vulnerable to malicious nodes.

Effort are being made to make wireless ad-hoc networks more secure [9], but there is still more work to be done. It is very crucial, for the whole future of being able to utilize MANETs, to have a reliable security concept in place.

5 Discussion

There are several frameworks for P2P solutions, which can be used in MANETs, in addition to the JMS and JXTA presented in the previous sections. One example is the Multi-level Peer Index (MPI) [11], which divides a geographical area into smaller areas in several levels. These are searched in turn extending the query to bigger areas.

The JMS implementation seems to be a bit basic and not very dynamic when considering the configurations files in each of the clients. Moreover, the transportation, which is best effort and the two other issues not addressed at all make this implementation not very flexible.

JXTA on the other hand seems to deliver a much clearer and better solution, it supports both best-effort and guaranteed delivery. On the other hand, the paper [8] does not define the improvements in such detail you could say anything for certain.

One of the main problems with P2P in MANETs come from the fact that making queries are very slow and inefficient. This is partly due to the protocol stack and that the queries are made on layers high up in the stack. In [10] different querying methods have been compared and the conclusion stated it is more efficient to have cross-layer design when implementing P2P protocols. This would seem to talk against solutions using JMS [14], JXTA [13] or other frameworks as a foundation when developing peer-to-peer systems for mobile ad-hoc networks. Maybe there will be a need to revise the current protocol stack and make use of cross-layering to be able to meet the demands of future mobile networks.

Other aspects include the operators and the mobile devices and what these will be capable of in the near future. Will we for example have all-IP networks for the mobile devices as well or is this a distant dream?

If we start looking at the consequences of having P2P in MANETs we can find several very interesting issues. For starters, using P2P in this way we could break the business models of all telecom operators. Sending media in a P2P fashion will only result in data transmission inside a multi-hop network. Moreover, if there is no infrastructure available, how can anyone charge for the data being transmitted? Today’s networks rely on the infrastructure to implement the charging mechanisms, but when removing it you will no longer have the control.

Even more copyright protected media will be shared inside instantaneous networks. This will also fall outside controlling possibilities.
Direct access to mobile devices is an effective driver for spamming, viruses, spyware and other malicious software. In [8] Mario Bisignano et al. suggest a code sharing service, which of course would be nice if it would be secure and reliable. However, time and again we have been shown that there is nothing reliable and secure, so this feature could be used by malicious code to spread between mobile nodes. This is a big threat P2P in MANETs has.

The near future will definitely provide some level of P2P in MANETs, but global, or even big, infrastructure-less communication is still an utopia.

6 Conclusion

This paper presented two frameworks used to implement P2P for MANETs: extended versions of JMS and JXTA. The research work in this area is still in the beginning of the journey to finding an efficient and well-working solution, so it is quite difficult to state anything concrete about the performance, security, reliability, efficiency or other metrics these solutions have.

One thing is clear, we will most likely see P2P in MANETs in the very near future and this could revolutionize the whole wireless world of communication. The main players in the industry are of course well aware of this, so it is highly unlikely that we will have all-IP networks with no means of control with respect to charging. However, the business is changing and the business models need to be revised in order to support the new and innovative solutions we will get.

References


