Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 3, Issue. 8, August 2014, pg.699 – 706

RESEARCH ARTICLE

MOBILE ADHOC NETWORKS AND PTP NETWORK

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Abstract

In this paper we will discuss about mobile ad hoc network (MANET) that is also known as mobile mesh network is a wireless network that use wireless transmission for communication and do not rely on any central coordinator. We will also discuss bootstrapping of PTP network. Mobile nodes that are within each other's radio range communicate directly via wireless links, while those far apart rely on other nodes to relay messages as routers.. Embodying the slogan "networking without networks," both abandoned traditional client/server model and disclaimed pre-existing infrastructure. However, their status quo levels of real world application are widely divergent. P2P networks are now accountable for about 50 ~ 70% internet traffic, while MANETs are still primarily in the laboratory. Mobile Ad-hoc Networks (MANETs) and Peer-to-Peer (P2P) networks are vigorous, revolutionary communication technologies in the 21st century. They lead the trend of decentralization. Decentralization will ultimately win clients over client/server model, because it gives ordinary network users more control, and stimulates their active participation. It is a determinant factor in shaping the future of networking. The interesting and confusing phenomenon has sparked considerable research effort to transplant successful approaches from P2P networks into MANETs. While most research in the synergy of P2P networks and MANETs focuses on routing, the network bootstrapping problem remains indispensable for any such transplantation to be realized. The most pivotal problems in bootstrapping are: Automatic configuration of nodes addresses and IDs, and Topology discovery and transformation in different layers and name spaces.

1. Introduction

It is interesting to notice how research effort and real world application interact in completely different ways for peer-to-peer (P2P) overlay networks[1] and mobile ad hoc networks (MANETs). In former case, successful business applications (if we disregard those notorious legal issues and focus on technical aspects) aroused public interest and initiated active

In latter case, ardent theoretical research leaded and dominated the whole area for more than a decade; however, no generally acknowledged application except Bluetooth has been developed yet. We do not count IEEE 802.11 – the popular Wireless LAN standard with a cute nickname Wi-Fi, developed by IEEE Working Group 11 – because it actually is not a MANET. In fact Wi-Fi is not directly comparable to MANETs; it is just a physical and MAC layer extension of wired network. To be able to work at normal status, Wi-Fi always needs access points, which are

against basic defining rules of MANET. The malformed resource distribution has set off a warning signal in MANET's community. In addition the inherent homogeneity between P2P networks and MANETs has reminded scholars the probability of transplantation for a long time. More and more researchers have initiated comparative study and remarkable achievements in the synergy of P2P networks and MANETs – or use another more popular term, P2P over MANETs – has been reflected in publications.

1.1. Conceptual Framework

To fully understand the objective of this paper, that is, bootstrapping structured P2P networks over MANETs, following concepts need to be clarified.

1.1.1 Structured P2P Networks

Structured P2P networks use fixed topologies like ring or grid for routing. Nowadays structured P2P overlay networks have become a convenient template paradigm for numerous diverse distributed services. The fundamental abstraction, on which all kinds of applications are based, is key-based routing. Keys are mapped to nodes. Routing a given key is to find the host node responsible for the key. The overlay topology is defined by neighbourhood relations specified by local routing tables on all nodes. Both key allocation and key-based routing are via Distributed Hash Table (DHT).

1.1.2 Distributed Hash Table

A DHT distributes data over a structured P2P network with aid of a fixed topology. Basic storage unit and data structure are (key, value) pairs. Node ID is homogeneous to a key. Hence a (key, value) pair could be mapped to a node by hashing the key. Each node is responsible for some section of the key space. The power of a DHT lie in its efficiency to quickly find any given (key, value) pair. The efficiency comes from carefully designed topology structure, node data structure and routing strategies seamlessly integrated into the topology. Basic DHT operations are

- Store(key; value): node ID ← (key; value)
- Locate(key): node ID ← Locate(key) // Also called Lookup
- Retrieve(key): value ← Retrieve(key)

1.1.3 Bootstrapping a Structured P2P Network

Bootstrapping is the automatic self-organizing procedure to initialize the network and all nodes inside the network, such that the structure P2P network can smoothly start its normal operations. It involves three tasks:

1. Node address automatic configuration (assignment);
2. Setting up the specific network topology
3. Building node data structures (DHT).

MANETs and P2P over MANETs: A common circumvention technique is using idealistic assumptions, which often do not hold in reality and make application-oriented implementation impossible.

1.1.4 Bootstrapping a Chord over MANETs

This is just a special case of the task described in last section. Chord is probably the most popular structure P2P network. Now the model covers all seven layers in the entire ISO/OSI network model/protocol stack. So we need carry out all three tasks in Section 1.2.3. In most case task (3) building node data structures (DHT) is contained in task (2). Now we have two fundamental problems to solve: (1) node address automatic configuration (assignment); (2) setting up the specific network topology. Chord uses ring topology, so (2) can be refined as: setting up a Chord ring over a MANET.

1.1.5 Node Address Automatic Configuration

As the name implies, node address automatic configuration is the protocol-controlled procedure in which all nodes are assigned unique addresses. Primary element of computer networks is node, which stands for an individual electronic device, a computer in most cases. In the biggest network – Internet, there are hundreds of millions of nodes. To deal with a node among many other nodes, a mechanism is required to reliably distinguish the node from all other nodes. This mechanism is address configuration. Its basic job is to assign a unique address to this node. Only after a unique address is given to all nodes can nodes be accessed and exchange information with each other. Address assignment is foundation of almost all other pivotal network operations, such as routing, sending, receiving, synchronization, unicast, multicast, broadcast, etc.

In wired networks like Internet, via configuring protocols like TCP/IP and data structure like routing table, node address can be set manually and statically by human operator. Typical applications for a MANET are emergence response,

battlefield strategic communication, and temporary casual meeting. A MANET is usually set up impromptu without expectation. Therefore the manual approach for address assignment is not appropriate for MANETs because of their dynamic and volatile nature. Automatic, program controlled configuration should be employed for address assignment in MANETs. As shown in Figure1.1, P2P networks usually sit at upper layers of protocol stack, while MANETs are located at lower layer (generally below transportation layer). A P2P network has its own node address at application (overlay) layer, which is more often called node ID. A MANETs has a MAC address at MAC/Physical layers, and has routing address at Network layer as well. The address Automatic Configuration problem applies to both MANETs and P2P networks. However, node ID at P2P overlay layer is usually cryptographically hashed according to application. So the problem is more often left for MANETs. The essential question is how to assign unique address to all nodes in a MANET with optimal time complexity, storage complexity, and message complexity.

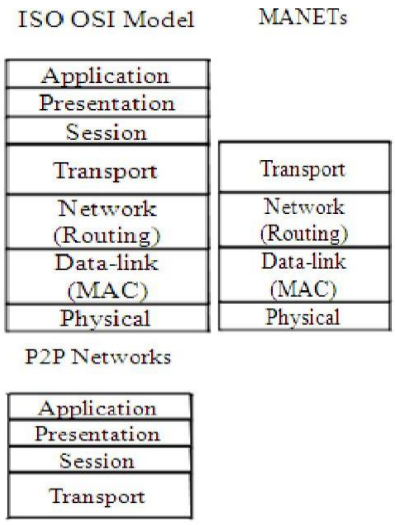

Figure 1: MANETs and P2P networks in protocol stacks

2. Peer-to-Peer Overlay Networks

P2P overlay networks provide fast, accurate, and scalable resource discovery, resource sharing, and storage services without a central controller. The concept of peer-to-peer networks first appeared in the mid 1990s. As file sharing platforms, especially to distribute MP3 music files over Internet, peer-to-peer networks turned into a hot topic in the late 1990s. A traditional P2P network is built upon IP. It uses IP as the communication platform. An IP capable host can reach anyone and anything attached to the Internet or other IP networks like IEEE 802 family by an IP address. However, IP layer could tell a host how and where to find a given content or another participant host. This is done by P2P overlay networks (systems). The basic task of P2P overlay networks is to connect to other peers and find out interesting content.

These P2P networks are completely distributed and self-organized networks. By P2P jargons, a host is called peer, because all hosts usually have same status, share same responsibility, and the relationship among them is characterized by equality. Unused bandwidth, storage, CPU cycles at the edge of the network are utilized. Peers enjoy great freedom and privacy. Consumers are also producers, so aggregate resources grow exponentially with utilization. There is no single point of failure in a P2P network.

The emergence of P2P overlay networks was a counteraction against long time tradition of client/server model in computing and communication society. In the client/server model, powerful, reliable servers provide data and services; clients request data and services from servers. The client/server model has proved to be so successful by its famous offspring like World Wide Web, database systems, and FTP. However, it has following inherent defects:

1. Need central controller
2. Presents a single point of failure
3. Unused resources at the system edge
4. Poor scalability
5. Dictation in which terminals feel like slaves

3. Related Works in P2P Systems over MANETs

Generally, there are two schools of research in integration of P2P and MANETs. First school builds their work upon existing P2P systems and MANET protocols. They have more legacies from MANETs than from IP. Their systems are likely small and efficient. The second school does not copy or adapt existing protocols or approaches; instead they ignore layer models in P2P and MANETs and try to set up something different. However, all research is historical; many of them actually have more heritages in IP than in MANETs. Many schemes proposed by this group have index or indexing in their name. Their systems are usually complicated, heavy-weight; and many implementations only have good performance with full support from platforms and operating systems. Many literatures in this group mixed up basic concepts, like comparing P2P document search with MANET routing. [LW2002]

In first school, Dynamic P2P Source Routing (DPSR) [HPD2003] and Ekta [PDH2004] by Y. C. Hu et al are among few that feasibly deviate from IP framework. They integrate Pastry [RD2001] and DSR [JM1996] at network level. Almost everything from Pastry is inherited; but in the low level implementation, they substitutes IP address in Pastry routing tables and leaf sets with DSR source routes.

However, IP address is still their foundation for almost everything, from self organization, DSR implementation, to setting up of Pastry overlay. And they assume original IP addresses are a prior configured. It is a rather impractical assumption.

In the second school, 7DS [PS2001] used cooperative caching concept to implement P2P file sharing in MANETs. However, using their techniques, the success rate of a search is not predictable and highly depends on the search locality in the system. Passive Distributed Indexing in ORION designed by C. Linder Mann et al [KLW2003], [LW2002] is not closely related to MANETs except mobility model. S.Y. Lee et al proposed Backtracking Chord and Redundant Chord [LJLQC2004], however, they did not describe how Chord was built on MANETs and what network layer protocol was used.

Konark service discovery and delivery protocol [DVH2003], [HDVL2003], designed by N. Desai et al, simply assumes an IP level connectivity among devices in the ad-hoc networks. It also assumes network support for routing multicast traffic when a node leaves or several networks merge. These assumptions are extremely unrealistic, almost equivalent to the hypothesis that without any effort a perfect P2P over MANET's system already exists, from physical layer to transport layer. The Proem platform, proposed by Gerd Kortuem [Kortuem2001], has similar problem in practicability. It bypasses IP, but needs IP addresses for all nodes, TCP/UDP, and SOAP for XML. On the other hand, Multi-level Peer Index developed by Mei Li et al [LLS2004] is very constructive in this group.

4. USING NON-IP ADDRESS IN MANETS

Many researchers are exploring dynamic IP address assignment in mobile ad-hoc networks, while much less effort is committed to non-IP addressing. The overwhelming success of TCP/IP in last two decades may be a good explanation. The pressure to connect to the Internet and keep all IP-oriented applications available might further explain the difference from a more pragmatic viewpoint. Nevertheless, these practical concerns are not necessarily tenable. To reach the Internet or other external networks, few gateway nodes could establish good enough interface. To access IP-oriented applications, a virtual IP overlay layer could be built upon non-IP transport layer; and an ARP like protocol could implement the address translation.

Let's first define stand-alone MANETs as MANETs which do not connect to Internet or other wired networks with cumbersome infrastructure. Stand-alone MANETs support typical, or to be precise, signatured, Manet's applications like emergency response, battlefield C3I systems, and impromptu laptop communication in conference.

Nodes in Network / Addressing Scheme	200	400	600	800	1000
128-bit Flat Address	0	0	0	0	0
32-bit Flat Address	0	0	0	0	0
IP Class A	0	0	0.2	0	0
IP Class B	0.2	0.4	2.2	5.2	6.2
IP Class C	81.8	318	708	1237.6	1949.8

TABLE1 COLLISION IN SMALL MANET

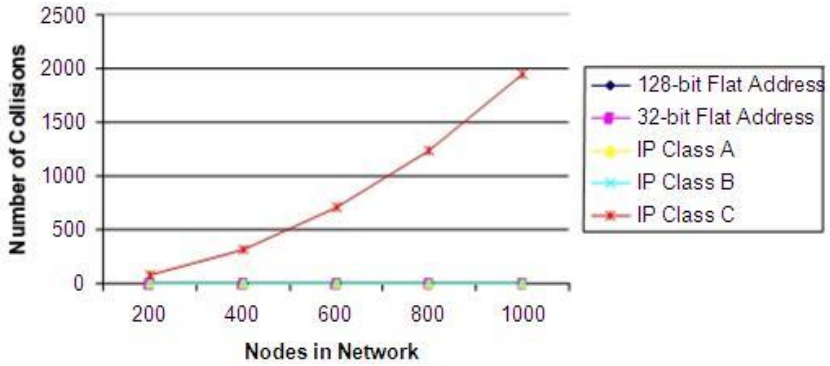

Fig 2: Collision in small MANET

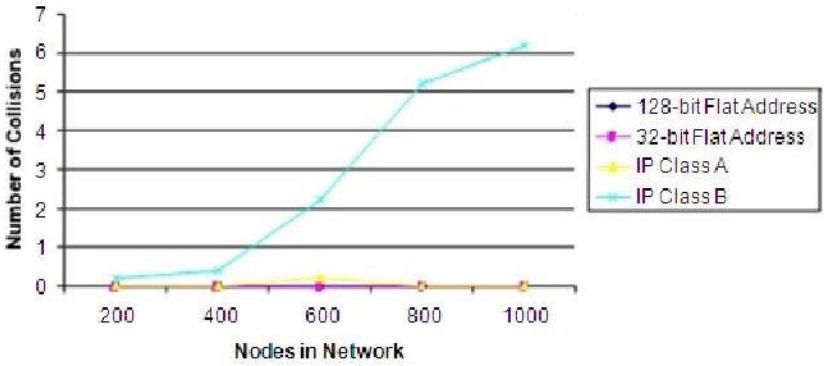

Fig3: Collision in small MANET without IP class C

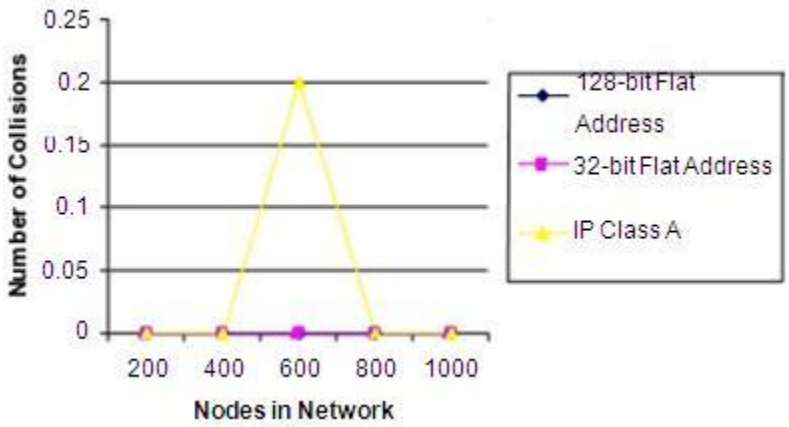

Fig4: Collision in small MANET without IP class B and C.

Table 2: Collision in medium MANET

Nodes in Network / Addressing Scheme	2000	4000	6000	8000	10000
128-bit Flat Address	0	0	0	0	0
32-bit Flat Address	0	0	0	0	0
IP Class A	0.2	0.2	0.8	1.2	2.6
IP Class B	32.6	127.4	278.6	488.4	741.4
IP Class C	7834	31307.4	70385.6	124917.8	195495.4

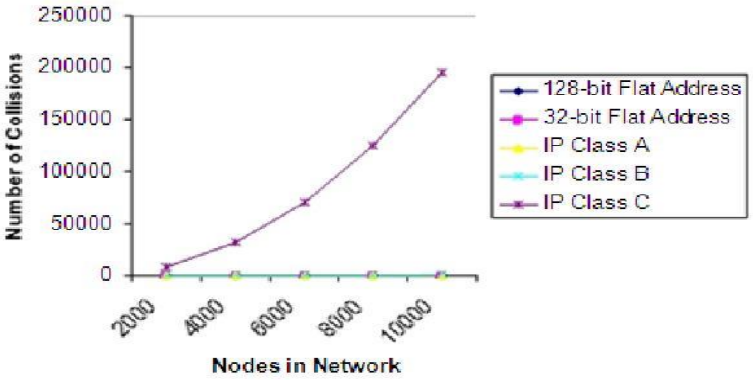

Fig5: Collision in Medium MANET

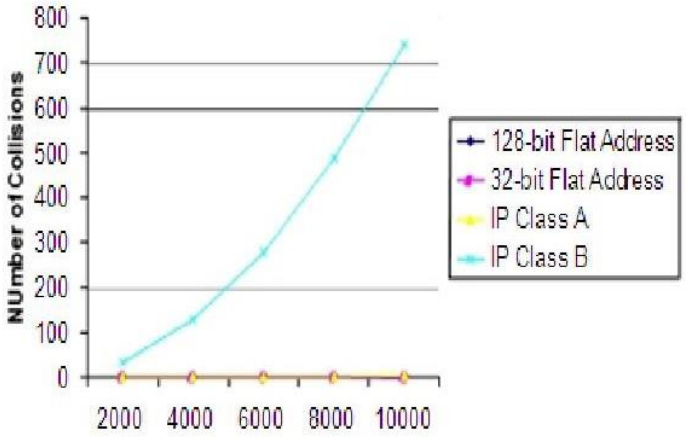

Fig6:Collision in Medium MANET without IP class C.

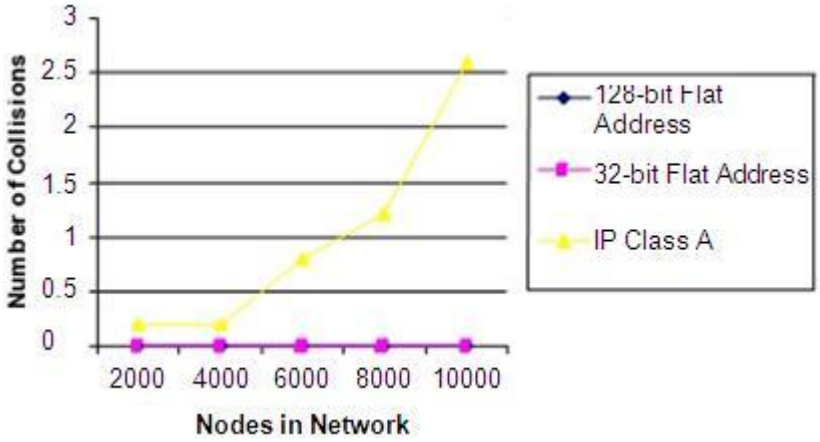

Fig7: collision in Medium MANET without IP class B and C.

5. FLAT ADDRESS PEER-TO-PEER SOURCE ROUTING

The FAPSR protocol has completely liberated peer-to-peer systems in ad-hoc networks from the shackle of old stereotype of IP and IP addresses. It opens up a space for efficient and light-weighted protocols. In this paper, we adopt flat address format for both DSR at network and transport layers and Pastry at application layer. This way we have avoided all complicated IP related problems in systems automatic configuration, routing, and maintenance. Other MANETs routing protocols could be easily adapted to this paradigm as well. Many MANETs routing protocols are compatible with it.

6. RING CONSTRUCTION

In computer networks, topology is frequently used to define relationships such as "which node is directly connected to which node," or "which node is neighbour of which node." For any structured P2P overlay network, overlay topology is crucial to its survival and success. That is why they are named structured P2P networks.

When bootstrapping a structured P2P network, there are two options. One is starting with a single node, no matter if this node is really isolated from other nodes, or it is actually in a crowdy neighbourhood, the network always is jumpstarted as a single node networks. To build the required overlay topology, a very long time has to be spent before a decent topology is ready to use, since only way to expand the network is one by one node joining. Obviously this kind of bootstrapping is unacceptable, irresponsible, almost like an act of sabotage. No one would adopt this approach unless no alternative could be resorted to. Another approach is construct a significant scale overlay topology for each connected component after or while dynamic address assignment. With this option, a P2P system could advance into normal working status immediately after bootstrapping. Topology lays foundation for routing, looking up, retrieval, data placement, data dissemination, and data aggregation in P2P networks, especially P2P over MANETs.

Structured P2P systems impose specific local topological relationships between peers, which in turn form a global structure. Topology is one of dominant factors that affect efficiency, robustness, and feasibility of algorithms. Application of network topology is far more beyond the above list. For example, Jelasity and Babaoglu have shown that problems such of network clustering and sorting can be transformed into topology problems and could be solved by specific topology construction.

7. Conclusion

This research paper targeted at the important intersection point of two popular research topics in computer networks, namely, peer-to-peer networks and mobile ad- hoc networks. In this paper, we have investigated existing successful and failed research efforts in synergy of P2P networks and MANETs and made two ground- breaking contributions to the specific field of bootstrapping P2P networks over MANETs.

Our first contribution is the proposal of a non-IP automatic address configuration scheme. We analysed advantages of this scheme comparing to other IP-based dynamic addressing approaches. We found that IP-based schemes waste the precious bits in MANETs. The requirement for IP address unnecessarily makes the addressing task more complicated. The only benefit of keeping IP in MANETs is it is easier to interface with present Internet and various existing applications. However, these excuse hardly forms any obstacle for our non-IP addressing scheme. The non-IP addressing can easily circumvent

Internet connection problem by using a few wired network gateway. For application compatibility, we can just use a virtual mapping layer to convert IP address and our non-IP address into each other, such that traditional IP-based applications could be kept in use above our proposed scheme.

Along with the non-IP addressing scheme, a novel protocol suits FAPSR is also developed for building Pastry P2P system over MANETs. The major difference of our approach with existing approaches like DPSR and Ekta is its integration of automatic configuration to routing protocol. With support of our non-IP addressing scheme, fast crypto-graphical random number generators could be employed directly in address assignment with very low possibility of duplicate addresses.

We believe flat address is a better choice than IP address, not only because it is collision free, but also because of its great simplicity and ease in network operation. More comparison study between flat address approach and IP approach should be conducted to elaborate the advantage of flat address scheme.

Our second contribution is a brand new topology construction protocol, specifically ring construction protocol, for building popular P2P systems like Chord and Pastry over MANETs. Our approach inherited successful topology construction methods in P2P over Internet society. We believe our approach is the first successful attempt to build ring in P2P ID space over MANETs.

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