On Mobile Mesh Networks

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***Abstract*—With the advances in mobile computing technologies and the growth of the Net, mobile mesh networks are going through a set of important evolutionary steps. In this paper, we survey architectural aspects of mobile mesh networks and their use cases and deployment models. Also, we survey challenging areas of mobile mesh networks and describe our vision of promising mobile services. This paper presents a basic introductory material for Masters of Open Information Technologies Lab, interested in modern mobile services.**

***Keywords*—mobile ad-hoc networks, wireless ad-hoc networks, social mesh networks.**

I. Introduction

Mesh networking is a type of network topology in which a node (device) transmits its own data as well as serves as a relay for other nodes. In other words, all nodes cooperate in the distribution of data in the network. The word 'mobile' adds mobility for nodes.

There are different attempts to classify mobile mesh networks [1]. We will follow to the below-described classifications. Three main classes are:

Mobile Ad-hoc NETworks (MANET)
Wireless Mesh Networks (WMN)
Social Mesh Networks (SMN)

A mobile ad hoc network (MANET) is an infrastructure-less, multi-hop, continuously self-configuring network of mobile devices. In computer networking, a term 'ad hoc network' refers, in general, to a network connection established for a single session. The wireless standards (Bluetooth, Wi-Fi, etc.) allow direct communications among network devices within the transmission range of their wireless interfaces (Figure 1)

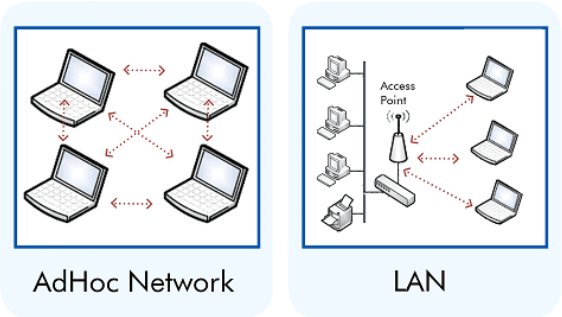

Fig. 1 Ad hoc vs. Lan [2]

In a multi-hop mode, network devices can transfer data for other devices (Figure 2).

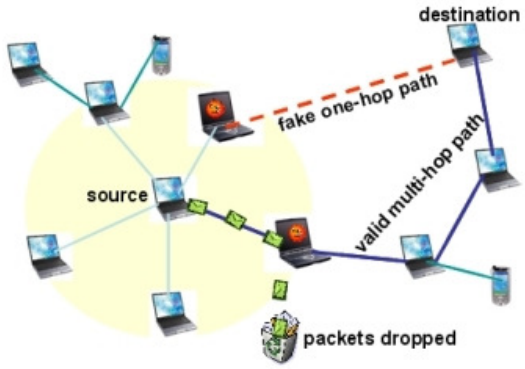

Fig. 2 Multi-hop path [3]

In MANET nearby users directly communicate (via the wireless-network interfaces of their devices) in ad hoc mode not only to exchange their own data, but also to relay the traffic of other network nodes that cannot communicate directly [4].

A vehicular ad hoc network (VANET) uses cars as mobile nodes in a MANET to create a mobile network [5]. A VANET turns every participating car into a wireless router or node.

There is MANET Internet Engineering Task Force (IETF) working group [6], which, inheriting the TCP/IP protocols stack layering, assumed an IP-centric view of a MANET [7].

Authors in [8] propose a variation of MANET – Autonomous Mobile Mesh Networks (AMMNET). In a standard wireless mesh network, stationary mesh nodes provide routing and relay capabilities. They form a mesh-like wireless network that allows mobile mesh clients to communicate with each other through multi-hop communications. When a mesh node fails, it can simply be replaced by a new one, and the mesh network will recognize the new mesh node and automatically reconfigure itself. The mobility of the mesh clients is confined to the fixed area serviced by a standard wireless mesh network due to the stationary mesh nodes. In contrast, an AMMNET is a wireless mesh network with autonomous mobile mesh nodes. In addition to the standard routing and relay functionality, these mobile mesh nodes move with their mesh clients and have the intelligence to dynamically adapt the network topology to provide optimal service. In particular, an AMMNET tries to prevent network partitioning to ensure connectivity for all its users. This property makes AMMNET a highly robust MANET.

A wireless mesh network (WMN) is an infrastructure-based network organized in a multi-hop mesh topology of static routers with single-hop connected mobile clients. In

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other words, there is no direct connectivity between clients (Figure 3).

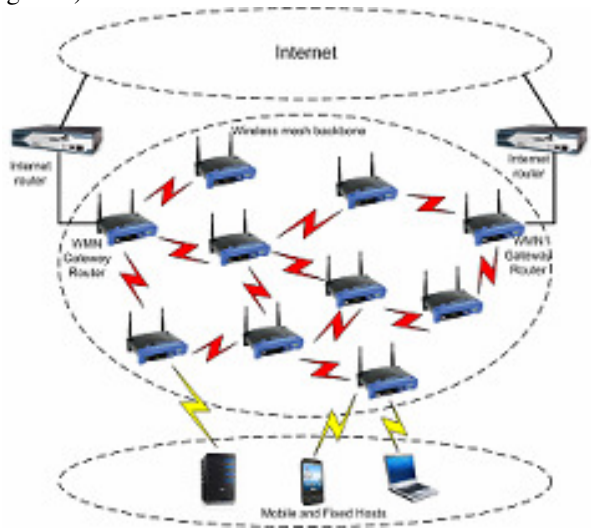


Fig. 3. WMN [9]

Social Mesh Networks use existing user equipment (mobile terminals) via multi-hop connections outside the cellular infrastructure. For example, Facebook has designed a system that would allow individuals and advertisers to make direct connections to those physically nearby that share similar interests or are open to receiving certain advertisements [10].

Under the envisioned system, a wireless device would establish a connection with other wireless devices nearby. The communication would be based on a direct link between the devices. Each device might be linked to one or many other devices, depending on the density of people in a certain area, and each would be open to sending, receiving and relaying messages as part of the mesh network.

Because the network is based on direct connections, the approximate location of users can be determined. For example, if a device has a 100 meter range, then all other devices it is in direct contact with could be determined to be within 100 meters. If those devices acted as relays, then a second level of devices could be determined to be within 200 meters and so on. The number of relays, or "hops," lies at the heart of the envisaged system [11].

II. Use cases

In general, MANET applications belong to the military areas. The typical applications include:

Military battlefield: ad-hoc networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles, and military information headquarters.

Emergency: ad-hoc can be used in emergency/rescue operations for disaster relief efforts, e.g. in fire, flood, earthquake. Ad-hoc networks can create the infrastructure for emergency communications where the default communication infrastructure does not exist or damaged. Actually, it is very close to a battlefield too.

Personal: ad-hoc networks could form a short range networks for closed communities, conferences, group meetings, etc.

WMNs applications belong to the WLAN space. The typical applications are:

Wi-Fi connectivity in small/big business buildings/campuses;

Video monitoring, video surveillance and security systems;

M2M applications;

Social Mesh Networks rely on large user base for enhanced connectivity. The typical applications are described in the above- mentioned patent [11].

In one example, the neighbor type 'restaurant' may be sub-divided into multiple sub-groups, such as 'Italian,' 'Thai,' 'French,' and others. In another example, the neighbor characteristics depend on the content advertised by the neighbor, such as the specific value of store discounts. In addition, the neighbor characteristics may indicate a neighbor's interests or social activities, such as interests in poker, science fiction, or kung-fu movies.

Finally, enabling communications based at least in part on network proximity may also assist businesses in identifying potential customers. In one example, the owner of a pizzeria may only want to advertise a '7:30 special' to the customers who are close-by to the pizzeria to avoid advertising to customers who are too far away to take advantage of the '7:30 special.' In another example, a department store with a large number of diverse products may tailor its promotional advertisements to the customers shopping within specific store sections. Hence, customers shopping in a 'Women's Shoes' section may receive advertisements that are different from advertisements received by customers shopping in a 'Men's Suits' section. The interest list would also enable users to find others nearby that shared similar interests and hobbies or act as a filter for discovering existing friends that are in the area.

III. Applications

The typical application for mobile mesh is Serval [12]. It provides a free, secure phone-to-phone voice calling, SMS and file sharing over Wi-Fi, without the need for a SIM card or a commercial mobile telephone carrier. In other words, it lets your Android phone communicate with other Android phones running Serval Mesh within Wi-Fi range (Figure 4).

The SPAN project is a framework and proof of concept implementation of a functional Mobile Ad-Hoc Mesh Network (MANET) for the Android smartphone platform [13]. For example, SPAN turns your phone or tablet into a simple push-to-talk (PTT) radio. You do not need a cell plan, access point or even an Internet connection, just a bunch of friends with ad-hoc-enabled devices of their own (Figure 5).

Both projects are Open Source applications. And technical details could be obtained via source code studying. Note that both projects require root access on Android.

A project called Commotion Wireless is developing several software packages that allow people to create mesh networks using low-cost Internet and networking hardware, primarily Wi-Fi routers [14].

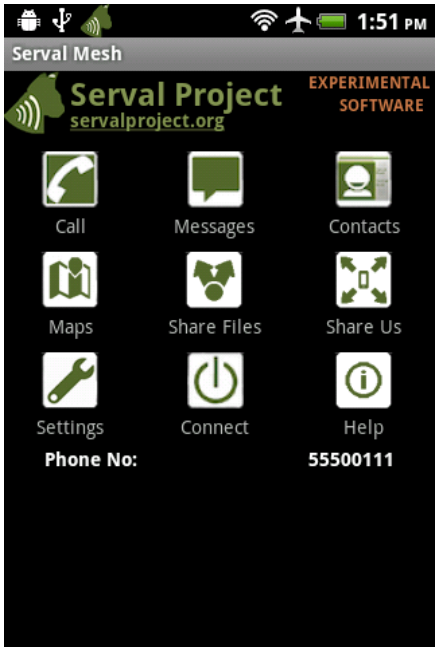


Fig. 4. Serval project

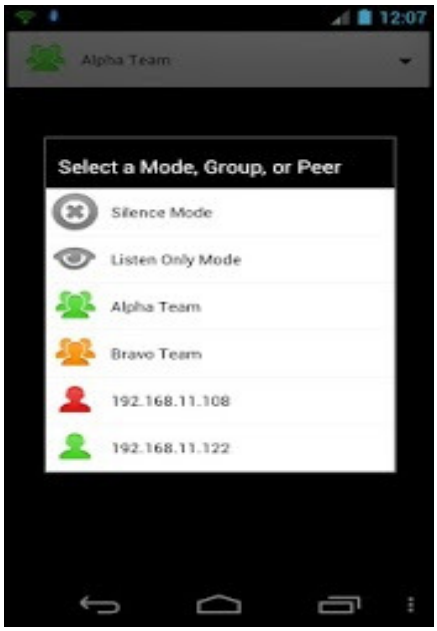


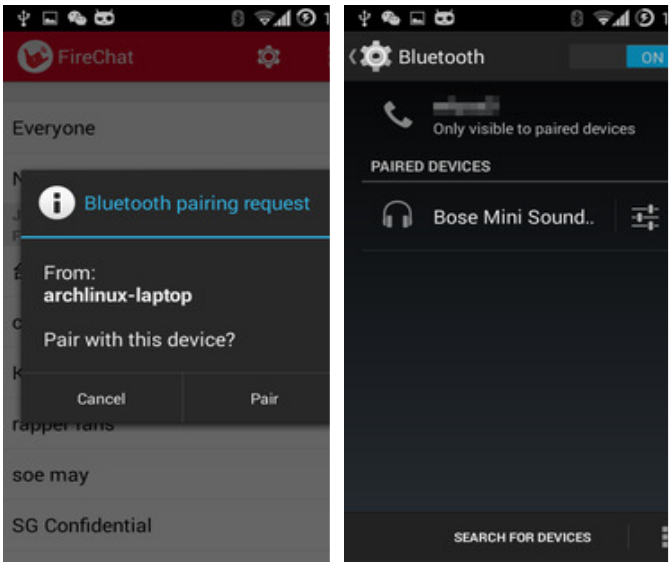
Fig. 5 SPAN project

Some communities in US already have Wi-Fi-based mesh networks built on Commotion's technology. The networks offer free Internet access by extending the reach of free connections offered by community centers; they also provide Web services and apps that function only within the local mesh.

Commotion Construction Kit lets create Community Networks [15]. Open community wireless networks digitally connect communities, and allow neighbors to share Internet access or use locally hosted applications. Neighbors are linked from rooftop to rooftop using wireless equipment. Ownership and management duties are distributed among the community. Technically, it is a modified operational system for wireless routers.

The next application from this area is Firechat [16]. Firechat (e.g., Android application) lets mobile users talk to each other using Bluetooth or Wi-Fi (even if the Wi-Fi is not connected to the Internet). As soon as one of the devices is connected to the Net, this connection could be shared.

Technically (based on the available information [17]), it uses Bluetooth pairing (Figure 6).



Fig, 6. Bluetooth in Firechat

Once Bluetooth is activated, Firechat will create two RFCOMM Bluetooth channel. One of them will be used for control and one – for data exchange [17].

As another possible protocol candidate for mobile mesh, we can mention Wi-Fi Direct specification [18]. Wi-Fi Direct devices can connect directly to one another without access to a traditional network. So, mobile phones, cameras, printers, PCs, and gaming devices can connect to each other directly to transfer content and share applications anytime and anywhere. Devices can make a one-to-one connection, or a group of several devices can connect simultaneously. They can connect each other for a single exchange, or they can retain the memory of the connection and link together each time they are in proximity [19].

As a completely new development in this area, we can mention Bluetooth Low Energy mesh [20]. According to the documents, the CSR Mesh protocol uses Bluetooth Smart to send messages to other Bluetooth Smart devices in the network which in turn send them onward. Messages can be addressed to individual devices or groups of devices. It is also possible for devices to belong to more than one group. Control is enabled via standard Bluetooth Smart enabled appliances such as light switches, or via the majority of smartphones or tablets available today [21].

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