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News about Mesh Networks

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Abstract- Nowadays, Wireless Mesh Networks (WMNs) are capturing a lot of interest from network operators and manufacturers of wireless equipments. Initially, WMNs were considered as a potential candidate to provide broadband access at a reasonable cost through allowing the extension of WLAN coverage from small hot spots to an entire city. Furthermore, relaying technologies which can be seen as a sub-version of WMNs are proposed to improve networks connectivity within WMAN networks.

In this paper we review the main technology in the area of Mesh and Relaying networks from standardization point of view, then we discuss the viability and the profitability, and finally we propose some new usages for such a technology.

I. Introduction

A mesh network is made up of a grid of nodes which collaborate to exchange information with their neighbors in a multi-hop fashion through adapted interfaces. Usually, mesh networks are based on wireless links, with the strong advantage to cover areas where no wired connection to a backhaul network is available or it is economically exorbitant. Therefore, mesh technology allows deploying and operating easily scalable wireless infrastructures with limited costs. This could be beneficial in rural areas and developing countries where the cost of infrastructure deployment is more than the revenue that can be generated.

To build up this multi-hop system, mesh technology is based on routing protocols which handle data transfer via mobile or fixed nodes of the network. Two key characteristics of mesh networks are self-organization and self-healing, which in turn guarantee their resilience even when a node or a link is broken. These characteristics together with the dynamic reconfiguration of the routing protocol ensure the network connectivity and survivability and hence service continuity in these networks.

Wireless Mesh Networks (WMNs) architectures can be classified into three main groups based on the functionality of the mesh nodes: i) Client mesh, ii) Infrastructure mesh and iii) Hybrid (or multi-layer) [1].

The first group provides peer-to-peer ad-hoc connections among the mesh clients without any pre-existing infrastructure, thus constructing multiple paths between each pair of mesh clients. In contrast, in the mesh infrastructure networks, a dynamic hierarchy is established between nodes (one father with one or several children), which implies a tree routing topology even if the mesh topology is kept at the radio level. These networks are usually based on the concept of level 2 routing protocols (tree topology, star topology, etc.). Finally, the architecture as a whole represents the hybrid (multi-layer) mesh architecture and is made up of relay nodes and access points. The relay nodes are dedicated to the data re-transmission, whereas access points provide the

radio interface to communicate with end-user terminals (laptop, PDA, sensor, actuator, etc.).

Mesh routing protocols can be introduced at different layers in the network, and are usually proprietary solutions with adapted mechanisms in the MAC layer. The type of mesh architecture required in a given situation is driven by the user and application needs for the content to be accessed. Nevertheless, the IEEE 802.11s group [2] is standardizing the WMN network for local area networks.

II. Possible usages for Mesh Networks

In the following, we discuss few practical usage scenarios and applications. These include: i) Single meshed home network managed by the network owner for broadband home networking applications where the topology evolution of the home network can be based on an AP range-extended mesh network configuration or on a multi-device cooperative mesh configuration. ii) A closed set of mesh nodes in a military environment where traffic flow must be kept confidential, thereby making the soldier-soldier communication more reliable and while covering a longer range. iii) An enterprise mesh network eventually eliminating the Ethernet backhaul for office WLAN based networks, which are particularly useful in office networking scenarios and also for health and medical system applications.

Other examples include community mesh networks deployed by operators in residential zones for provisioning of grass-roots communities wireless networks allowing them to share Internet connections via gateways. Metro-scale mesh networks are a broader version of community mesh networks which covers an entire metropolitan area in order to capacitate different city, county/municipality wide efforts for wireless broadband services, intelligent transportation services etc. On the other hand, open mesh networks also provide excellent opportunities for mission critical applications and public safety efforts, particularly for emergency operations for disaster recovery situations for example and for vehicular communications. With the vision of future communication infrastructure, often being quoted with respect to the integration of all mobile and wireless nodes with the IP core; a viable application for mesh network technology would be to provide an alternate route, alongside WLAN and 3G etc.

Mesh networks also introduce an interesting business perspective when used along with wireless sensor networks. The interesting scenarios where the sensor-mesh combination will be useful are in industrial monitoring, home monitoring and building automation, environmental monitoring, value asset and perimeter security etc.

III. Current deployments

Various actors are interested in mesh technology, because it can be a good trade-off between network costs and acceptable level of service. We can cite Municipalities & public bodies in the US, utility companies (like water & electricity for wireless tele-metering solutions), dedicated service providers, cable-operators as Cablevision and Kerman, telecom operators for areas where wired broadband infrastructures are not widely deployed, and manufacturers of network equipments (like Motorola, Cisco, Ericsson).

Mesh technology knew a strong hype with Municipal Wi-Fi (MuniWiFi) deployments in the US in 2004 – 2006. A clear example is the *Regional Communication Systems network*

which is an emergency communication WMN used during the 2003 San Diego Firestorms allowing effective communication between fire, police and emergency services to cope with the situation. We notice that over 400 projects were planned in August 2007 in the US, but since then, important projects have been stalled such as San Francisco, Chicago & St Louis. In spite of these failures, the number of municipal Wi-Fi network have increased in 2007 and over 200 US municipal Wi-Fi networks are still active. In the rest of the world since 2005 several networks have been deployed in Europe, Asia & Africa: The Cloud (UK), Golden Telecom (Moscow), Kenya Data Network or LifeStyle Networks (Mumbai), etc.Their business model is usual ISP model with 100% private investments. These networks target in priority the high potential zones such as dense residential areas or business hotzones. Mesh technology has been deployed in more than 50 countries with over 1000 networks.

IV. Standardization

Several standardization bodies are actively working to define specifications for wireless mesh networking, targeting different types of networks. Dedicated IEEE Task Groups (TGs) have been established defining the requirements for mesh networking in Wireless Personal Area Networks (WPAN), WLANs, Wireless Metropolitan Area Networks (WMANs) and Mobile Broadband Wireless Access (MBWA).

The IEEE *802.15.5 TG* [3] was formed to determine the necessary mechanisms enabling mesh networking in WPANs. The challenge is in providing lightweight implementations for mesh networking techniques considering the limited resources in the digital devices. This standardization process is expected to provide an architectural framework enabling WPAN devices to promote interoperable, stable, and scalable wireless mesh topologies.

Facing the throughput degradation and the unfairness in IEEE 802.11 multihop networks, the IEEE *802.11s TG* [2] addresses the needs for wireless mesh in WLANs and aims to extend 802.11 architectures and protocols to provide ESS (Extended Service Set) mesh functionalities. The implementation of this specification shall be directly reflected over the existing PHY layer of IEEE 802.11a/b/g/n operating in the unlicensed spectrum of 2.4 and 5 GHz. The 802.11s standard would not be published before the beginning of 2009. Many companies propose products which support Mesh functionalities (Nortel, CISCO, STRIX, etc.), unfortunately, it is proprietary solutions since the standard are still under development

On the other hand, IEEE 802.16 [4] standard targets WMANs and comprises some TGs related to mesh networking. The WiMAX forum is working to ensure the interoperability of manufactured equipments using these standard suites. IEEE 802.16d standard supports the Mesh mode but only between the SS (subscriber Stations), though it was deleted from the 802.16Rev2 [5] standard.

The *802.16j TG* [6] was created for *Mobile Multihop Relay (MMR)* to extend the 802.16 standard with multihop relaying facilities. However, the supported topology is tree (Point to a Multi-Point Mode) and not a Mesh (Multi-Point to Multi-Point Mode). Only few companies propose prototypes for tests (ex, Thales). The IEEE 802.16j is expected to be available by the mid of 2009.

V. Market Penetration Rate

Despite the Golden Telecom deployments in Moscow and the one in Taipei City which select Mesh Network solution to offer wireless connectivity facilities over the whole city, the other Mesh deployments are limited to small areas. Indeed, the most important WLAN deployments rather consider the infrastructure-based mode.

This might be explained by two facts; the first one is that the cost of the Mesh equipments is still above the limit that makes the technology competitive [7] compared to the infrastructure based mode. The second is the lack of a viable economical model that motivates the operator to proceed to a large WiFi deployment.

One promising approach to increase the market penetration rate for the mesh technology is applying an open community mesh networks deployment approach, in which residential subscribers cooperate and open their mesh routers to external clients. This allows economizing the cost of mesh technology deployment and hence can increase the penetration rate of such technology. However, one challenge is the security. Efficient access control and security mechanisms should be in place in order to prevent malicious and non legitimate access that can not only harm the residential subscribers but also damage the whole network. Another challenge lies in finding the adequate business model that permits the acceptability of this approach by the residential subscriber, where rewarding mechanisms should be offered to this latter.

VI. Conclusion

Wireless mesh networks have emerged as promising new technology, where several vendors are offering services for their deployment. Furthermore, large companies and industry alliances are actively involved in the development of WMNs and several IEEE standards TGs are working on new standards for these networks. This paper introduced the different architectures of WMNs, and reviewed a number of interesting usage scenarios and current deployment for these networks. In addition, the different standardization efforts related to WMNs are presented and their market penetration is discussed.

From a network operator view, WMN is a promising technology especially in rural areas, developing countries and emergency communication; however, the cost of deployment of these networks will be the main driving factor for their success and market penetration on one hand. On the other hand, some technical challenges still need to be resolved to allow for their feasible deployment.

References

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