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Multicast group membership management in media independent handover services

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ABSTRACT

Currently we are witnessing an explosion of devices able to connect to a variety of wired and wireless access network technologies. This connectivity is increasingly integrating networks composed by sensors, actuators and even utility devices that use private and public networks to relay important information and measurements. The deployment of the so-called Smart Grid technologies allied to the rise of Machine-to-Machine communications require new mechanisms to optimally manage the change of point of attachment to the network of these huge clouds of nodes, assisting in tackling the scale of the problem. With this problematic in mind, the IEEE 802.21 WG started on March 2012 a new project, named IEEE 802.21d, group management services. This amendment establishes the required changes to the original specification, in order to manage the mobility of groups of nodes. This work follows closely the progress of the Task Group on the use cases, requirements and gap analysis, providing in addition a potential solution, integrating new group mechanisms, extensions to the MIH Protocol and associated security enhancements. This solution has been implemented and validated in a custom built testbed, with results showing that the utilisation of Group Control procedures through multicast signalling achieves a lower cost when compared with unicast signalling, in group handover and sensor information dissemination scenarios.

1. Introduction

In the last years we have been witnessing the explosion of multi-mode connected devices that take advantage of different technologies, aiming to improve the connectivity options of terminals. Although the use of several technologies is not something new, its current use is limited, since terminals are only able to connect to well known hotspots preconfigured by the user, without further intelligence. In order to overcome this limitation, providing new mechanisms for network selection and information sharing, the IEEE published at the end of 2008 the IEEE 802.21 specification [1]. The IEEE 802.21 standard on Media Independent Handover (MIH) Services aims at improving user experience in mobile terminals by providing a set of services that will help optimise the handover between IEEE 802-based and cellular technologies. In 2012, two new amendments to the base specification were published. The IEEE 802.21a [2] providing security services and the IEEE 802.21b [3] extending the basic functionality of the standard to support downlink only technologies. While developing this last amendment, several comments were received from Smart Grid/M2M related forums, pointing out the lack of a specific feature, corresponding to the mobility management of not a single node, but groups of nodes, addressing the requirements posed by these new applications and use cases.

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In order to tackle this requirement, the IEEE 802.21d Task Group (TGd) was created in March 2012. Although the applicability of the group management extensions is not limited to it, the main use case that triggered the IEEE 802.21d work was centred on the management of networks composed by large numbers of sensor/actuator networks. The operators of such networks require mechanisms able to scale with the number of nodes in order to e.g., handover portions of the network to a separate maintenance network, a perfect match for the group management features to be developed by the TGd.

Framed by the progress of the specification, this paper presents initial research providing a solution to the challenges posed by the new amendment. An initial description on motivation and background work is presented in Section 2, followed by an explanation of the role of IEEE 802.21d within the IEEE 802.21 WG in Section 3. The scenarios, requirements and gap analysis of missing features are presented in Section 4. Section 5 details the design of the proposed solution, specifying the new features developed and the different options that can be taken while addressing the problem space. Section 6 reports the results obtained from a prototype of the proposed solution developed over a real open-source IEEE 802.21 implementation for the purpose of this work, showing the pros and cons of using multicast communication in the concerned scenarios. Finally, the paper concludes with Section 7.

2. Related work and motivation

As explained in Section 1, the work performed at the IEEE 802.21d TG was initiated to specifically address the communication requirements (in terms of mobility control protocol) of applications scaling to thousands of nodes.

In the context of Smart Grid and Machine to Machine (M2M) communications, due to the diversity and extreme large scale properties of the network, the characteristics of the data and control traffic are not well known, increasing the complexity of managing mobility. Sample scenarios of the use of Smart Grid are the distribution of energy consumption measurements in a neighbourhood, where hundreds to thousands of nodes may send measurements once every e.g., 10 min [4]. In order to understand the magnitude of the problem being tackled, Table 1 presents the expected number of nodes that will be active in Japan households for different areas and number of nodes per household (M). As Table 1 shows, the number of nodes is expected to be very high, with ranges in the order of the thousands. This expected value is in line with other reports such as [5], where it is stated that the expected aggregated traffic in an IEEE 802.16p sector might scale up to 35,000 devices.

These new use cases require a reliable connection, hence nodes must be continuously searching for the best possible connection, involving a handover of Point of Attachment (PoA) in the cases where the current connection is poor. Due to the large amount of nodes involved in the communication, Group Control has been identified as one of the key challenges for this kind of network [6]. Mobility management in this scenario has several major challenges. Basically, the signalling required to move portions of these networks to a different point of attachment might increase the delay in the medium (since several messages, scaling with the number of nodes, are sent) and may also impact the accuracy of the measurements being reported by the sensors. This implications will be further elaborated in Section 6.

In these scenarios, the usage of multicast traffic capabilities increases the scalability of group information dissemination traversing the network [7,8], particularly at the network layer. However, group dynamics incur stringent conditions in the access layer, such as when concentrations of users occurring due to large numbers of passengers commuting in trains or buses leave the coverage of a wireless network, and have to select and handover to other networks. As another example, [5] also accounts for situations where surges in network access from a large number of devices, motivated by an outage or an alarm event in the network, can generate up to 35,000 access attempts over periods of 10 s, in large cities, having to maintain a 99% access success rate. These situations typically generate handover selection opportunities that occur simultaneous to all entities, where each node egotistically tries to select the best network based on individual information. As these situations create performance degradation and network congestion, they raise the need for controlling mechanisms operating over wireless networks, such as handover management procedures aiming to optimise wireless connectivity, while maintaining the need for operating in a media independent way.

Group Control implies that the system supports group addressing and handling of devices as clusters, imposing the same behaviour to group of nodes. Solutions for this issue, however, have been mostly concerned with increasing the level of awareness of the concurrency for optimal network selection. In [9] a comparison between mobile terminal and network controlled approaches was done, showing that the later one allowed for lower delays and handover rejection rates. The authors of [10] used an enhanced Proxy Mobile IPv6 message which aggregated the mobility information of different 6LoWPAN-enabled sensors, to reduce

Table 1
Foreseen number of nodes in Japan based on 2012 household data.[a]

	Area (Km^2)	# of Households (in 2012)	Avg. # of nodes per sq.km		
			$M = 1$	$M = 5$	$M = 10$
Special Wards of Tokyo	622	4,547,435	7311	36,555	73,110
Tokyo	2629	6,403,219	2435	12,175	24,350
Japan	377,900	51,950,504	137	685	1370

[a] *Source of data:* `http://www.metro.tokyo.jp/INET/CHOUSA/2011/02/60l2p200.htm`.