An overview of the issues facing powerline communications when providing broadband connection from the home gateway to home network end-devices

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Abstract: In-house mains wiring provides a ready-made, near ubiquitous, backbone to interconnect residential devices to the home gateway and provide users with utility like broadband services. Notwithstanding this, vendors to-date have tended to focus on simple point-to-point solutions that provide high data throughput. This paper gives an overview of some of the issues, and their possible solution, that need to be addressed if communication over powerline is to deliver broadband connectivity to all the mains sockets in a home.

1 Introduction.

Broadband networks are presently being upgraded by telecommunications operators to deliver IP enabled services such as telephony and television direct to the living room of homes. An essential component in the architecture to achieve this end is the Home Gateway (HG). The HG is a “device that provides broadband connectivity to the home and delivers services to, and from, an ever increasing number of end-devices in the customer environment” [1]. It is commonly accepted that if the HG is to achieve widespread user acceptance it must meet the minimum requirement of (a) providing low latency, low packet loss and high throughput connections; (b) avoiding the need for new wiring in the home; (c) covering the whole house while providing protection against unauthorized 'next door' access; and (d) being non proprietary, widely available and importantly low cost.

Though the Home Gateway Initiative [1] lists several technologies that may fulfil the above criteria; a number are specific to the United States leaving powerline and wireless as the most promising candidates for use in Western Europe. While wireless home networking based on IEEE 802.11a, has emerged of late as the preferred technology for distribution of data services within the home; studies suggest [2] it has a non-uniform coverage for data rates in excess of 15Mbits/s. Further, in the case of access points (AP) that experience interference from neighbouring properties the 'listen before talk' approach employed by the 802.11 MAC results in a significant reduction in throughput, such that the data rates needed for video distribution can no longer be achieved with any degree of reliability. This has prompted engineers to look afresh at powerline as an alternative in-house communication solution.

In-house electrical distribution networks have proven to be a harsh environment for sending data. In the unused quiescent state the medium is subject to varying impedance, considerable noise that is not white in nature and high levels of frequency-dependent attenuation. While in the used state when householders go about plugging in or switching off of devices the network topology changes with time. To cap it all the medium has to be shared between all active devices and in both directions of transmission imposing further constraints – half duplex. With this in mind the remainder of this paper addresses some of those issues that need to be understood and overcome if a holistic solution, encompassing powerline, is to be arrived at that provides whole house broadband coverage.

2. Standardisation Efforts.

As the momentum behind powerline technology in the home has grown the technology has coalesced into three industry groupings - CEPCA [3], UPA [4] and the HomePlug Alliance [5]. In an effort to come up with a standard acceptable to all parties the IEEE P1901 working group was charged in June 2005 with preparing a draft standard of the MAC and physical layer specifications for broadband over power line networks.

Although differences exist in their implementations CEPCA, UPA and HomePlug have accepted as part of their MAC protocol the need for a contention and contention free (CF) region – the CF being based on periodic Time Division Multiple Access (TDMA) allocation from a controlling master. The rationale being to provide an element of deterministic behaviour for delay sensitive applications such as telephony etc. This intention may[1] be undermined in the CEPCA and HomePlug systems by having a framing structure that is tied to the zero-crossing point of the underlying AC; resulting in a medium access window of 20milliseconds for the CEPCA proposal – or 40milliseconds for the HomePlug as it uses two AC cycle periods. This contrast with a period in microseconds for IEEE 802.11a and a recommended home network delay that should not exceed 5ms [5].

3. Unanswered Questions.

The characteristics of powerline are such that at any one time not all nodes will have bidirectional visibility of their neighbouring nodes (asymmetric connections being normal); some nodes even becoming isolated islands "hidden" from the other nodes in the network. The consequence is that hidden nodes and 1-hop$^+$ neighbour nodes, oblivious to the presence of beacons and unaware of the TDMA schedule for that beacon period, will establish themselves as competing controlling masters; accessing the medium in unison with other nodes thereby preventing end-to-end communication.

The issue is further complicated as latter day solutions fail to take into consideration the need for one system to co-operate with another in an adjoining property - in blocks of flats the fuse box will not filter carrier signals in the 1 to 30Mhz range needed for powerline communication (PLC) leading to propagation and therein interference.

While the IEEE P1901 work involves coming up with a coexistence specification to allow different hardware to share the powerline without interfering locally; this does not extend to a protocol to enable two or more PLC homes to cooperate and resolve how best to maintain the integrity of each others network whilst ensuring maximum throughput.

Borrowing from the cellular world a simple solution to this problem could be provided by dividing the available frequency band into a number of channels and re-using them in a regular repeating pattern – an approach proposed in [6]. The downside is that if we use *n* different channels then within each powerline cell only 1/*n* of the total bandwidth is available.

Reduced PLC performance obviously has a knock on effect on the marketing of the solution. At present we are at the early adopter stage of the market and as such companies tend to advertise PLC on the basis of data throughput; making no mention of the decreased performance as the number of node's increase. A re-appraisal of this approach in view of the eventual reduced working performance (see [7] for the benchmarked performance of commercially available powerline adapters) would be timely as history teaches consumers are quick to uncover and punish the promulgators of oversold items.

In any event the development of the HG market is likely to be delayed by consumer confusion over the optimum technology. For example, mobile operators are set to promise consumers the convenience of an omnipresent handset with the installation of indoor UMTS base stations (often referred to as femtocells) [8] in the home. But how will this fixed-mobile convergence solution play out in practice?

A number of studies have established that in spite of the publicity surrounding triple-play[2] consumers prefer single-play and double-play, mixing offers from different players; so any solution apart from being simple to comprehend needs to be built from the ground up to interoperate with other vendors offerings and to provide seamless broadband service. With this in mind, rather than going it alone and pioneering proprietary protocols, a more realistic strategy in Europe for the PLC community to take is

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1 The HG periodically generates a beacon with information about the temporal locations of TDMA and CSMA allocations for the stations in the network but the mapping of slots in a frame is implementation specific. In view of the dearth of information for multiple node environments we are not accurately able to gauge the significance of this observation but note it as something to be aware of.

2 Video, voice and data. Quad-play includes mobile telephony.

to evolve a hybrid solution that adopts the MAC layer of the 802.15.3[3] wireless standards. Such a tactic would avoid any threatened CEPCA / HomePlug deadlock in the IEEE P1901 coexistence WG and provide a quicker route to market. Although unorthodox this approach has already been pioneered by Texas Instruments with its coax-wireless home network proposal [9].

IEEE 802.15.3 is a natural fit for PLC as it has 4 channels set aside to serve applications requiring data rates in excess of 20Mb/s and allows for the parent coordinator to spawn child networks to extend the area of coverage; whilst also supporting, in the case of spectrum exhaustion, autonomous neighbour networks that exist entirely within a time window allocated by the parent. The concept of child and neighbour networks dovetails with our need to have a multi-hop network for total in-home coverage and the division of spectrum to enable the accommodation of our real-life next door neighbour's LAN.

4. Conclusions.

This paper has presented a brief outline of PLC and some of the problems that need to be tackled. Although the IEEE is presently engaged in an effort to arrive at a standard for PLC, the author contends that dominance of the WG by two large industry alliances will ultimately lead to stalemate resulting in no overall standard. Accordingly, in view that wireless technologies must play a significant part in providing whole home coverage due to the common acceptance of mobility, those individuals backing powerline for commercial gain would be better served by working with an established wireless standard to fill the gaps in coverage and provide a seamless TNL backbone to interconnect the various AP's.

3 As advocated by the WiMedia Alliance – http://www.wimedia.org.

References.

[1] http://www.homegatewayinitiative.org/

[2] The impact of power limitations and adjacent residence interference on the performance of WLANs for home networking applications, S. Armour, A. Doufexi, B-S. Lee, A. Nix, D. Bull, IEEE Transactions on Consumer Electronics, Vol. 47, No. 3, AUGUST 2001.

[3] http://www.cepca.org/home

[4] http://www.upaplc.org

[4] http://www.homeplug.org/home

[5] Network Interoperability Consultative Committee, ND1701:2006/03, Recommended Standard for the UK National Transmission Plan for Public Networks.

[6] A Coordination and Bandwidth Sharing Method for Multiple Interfering Neighbor Networks, D. Ayyagari, W.C. Chan, IEEE, 2004.

[7] Benchmarking and QoS of In-House Powerline Equipment for AV streaming Applications, B. Jensen, H. Slavensky, S. Kjaersgaard, IEEE, 2006.

[8] http://www.ubiquisys.com

[9] 802.11 Over Coax – A Hybrid Coax-Wireless Home Network Using 802.11 Technology, L. Ophir, Y. Bitran, IEEE, 2004.

Appendices.

For the purposes of the present document, the following abbreviations apply:

AP	Access Points
CEPCA	Consumer Electronics Powerline Communication Alliance
CSMA	Carrier Sense Multiple Access
HG	Home Gateway
IEEE	Institute of Electrical and Electronics Engineers.
IP	Internet Protocol
LAN	Local Area Network
MAC	Medium Access Control
PLC	Powerline Communication
TDMA	Time Division Multiple Access
TNL	Transport Network Layer
UPA	Universal Powerline Association
UMTS	Universal Mobile Telecommunications System
WG	Working Group