Project	IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>	
Title	**Network Architecture options for GRIDMAN – Smart Grid applications**	
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Re:	Call for Contributions in C802.16gman-09/0001	
Abstract	This contribution presents possible network architectures for GRIDMAN – Smart Grid applications and proposes modifications to draft PAR in IEEE 802.16-09/0068r2	
Purpose	To be discussed and agreed by SG – GRIDMAN as part of draft PAR presented to WG	
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Network Architecture options for GRIDMAN – Smart Grid applications

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Introduction

The increasing realization that considerable savings in consumer and national spending on energy can be obtained by intelligent control of its generation, distribution and consumption have brought Smart Grid initiatives in the US as well as in Euro zone and other markets. The Smart Grid is a natural successor to, and extension of, the smart metering. In their simplest form, smart meters simply provide means for monitoring and control of usage per household or per large appliance (such as a full house A/C) that justifies its own meter.
The Smart Grid concept could extend the ability to multiple energy consuming appliances that can be found in the home such as refrigerators, water and space heaters, window A/C units, lighting fixtures and even the ubiquitous charger. With real time energy pricing information, algorithms could be implemented to control the appliances to achieve a desirable tradeoff between comfort and energy costs. In houses that are equipped with energy generation devices (e.g. photovoltaic cells), similar control algorithms can determine when to sell the energy to the utility company and when to use it locally.

To achieve energy – and money - savings, monitoring and control devices must be installed in most energy consuming or generating appliances in the home. While these savings will accumulate over time, the savings per appliance will take some time to accumulate. A large initial investment per device will prove a deterrent to widespread use and must therefore be avoided. The initial investment per appliance must therefore be small fraction of the cost of the appliance. With many appliances at the sub $100 range (e.g. a window A/C unit in US retail) the price of the communication and control device is severely constrained.

Similar considerations apply to the communications network that may be deployed by the energy company. For those, the energy savings of the consumers actually represents reduced revenues and therefore a potential for reduced profits. The big benefit of Smart Grid to utility companies is in that it reduces peak load and therefore saves the cost of purchasing and operating extra generating equipment used in peak times only. Large operating expenses for communications network will prove prohibitive, as expressed by the reluctance to use existing cellular networks for the purpose. Deploying their own networks, utility companies will need to minimize deployment cost by minimizing the number of points of presence (POP, e.g. base stations).

The above suggests several design guidelines to Smart Grid communications:

1) Devices used in in-home appliances should be cheap and therefore low power, short range and possibly low data rate.
2) Devices used in home to POP should be long range and therefore high transmit power.

Complying with the first guideline requires that a concentrator and relay network node exist at or near the home. Doing so will provide an additional benefit in keeping local traffic local and reducing network load. We note that the concentrator node both carries traffic from many devices and can be used for policy and software upgrades download, which leads to another guideline:

3) Relaying devices used for home to POP link should support higher data rate

Finally, we should also note that in some cases the monitored devices aren't connected to electrical supply

(e.g. gas meters) which leads to another guideline:

4) Smart Grid devices should have low battery consumption

Out of all IEEE-802 standards, 802.16 devices are uniquely suitable for high data rate long range applications and therefore for the home to POP communication link. The in-home communication could also be done using 802.16 devices which leads to a homogenous network. Alternatively other RATs could be deployed which leads to heterogeneous networks. Both approaches are described below.

Finally, the considerations here are particularly relevant to residential applications. There is no reason why both approaches cannot be deployed within the same network. For example, residential communications could be done using the heterogeneous approach while electrical grid monitoring could use the homogenous approach.

Smart Grid using Homogenous Networks

In this approach we assume that all network communications devices are 802.16 compliant. A typical deployment would include several types of devices. Macro base stations would serve as the utility company POP and a connection to backhaul. Low cost 802.16 devices with possibly reduced capabilities (low power, low data rate) would be installed in appliances. These could communicate directly with the base station. Alternatively, 802.16 – compatible (802.16m or modified) relays or MS acting as relays could relay communication to and from the devices in the appliances to the BS. Additional relays may be deployed to further extend network coverage.

This approach has an advantage in that it requires the procurement and management of a single technology only. On the technical side, it allows the use of 802.16 multi-site and interference mitigation techniques and therefore has the potential for higher cell spectral efficiency.

An issue with this approach is that it isn't clear whether 802.16 compatible devices can be made cheaply enough to compete in cost with some other technologies (e.g. 802.15.4, Bluetooth, etc.).
An example of a homogenous Smart Grid is depicted in Figure 1.

Smart Grid using Heterogeneous Networks

In this approach we assume the use of two or more disparate technologies. The in-home traffic can be carried by home area network (HAN) devices (802.15.4, Bluetooth, etc.) to a local access point / router / gateway that may be installed per residence or per a group of residences. An 802.16 mobile device will carry data between the router and a base station. As for the homogenous networks, relays or other mobiles acting as relays can be used to extend the cell coverage and reduce the number of POP.

The resulting network isn't as efficient but has the advantage of very low cost devices for the appliances.
An example of a heterogeneous Smart Grid is depicted in Figure 2.

Text Proposal

Propose to modify draft PAR in 80216-09_0068r2 as follows: (Blue – new text)

5.2 Scope of Proposed Standard:

This amendment specifies OFDMA PHY, MAC and management and data interfaces enhancements to IEEE Standard 802.16 for operation with increased robustness in degraded infrastructure. This amendment will support path redundancy, mobile and local relaying, multi-hop relaying, Mobile Base Station, Low Duty Ratio, optimizations for low cost mobiles, as well as operation in licensed, unlicensed and lightly licensed spectrum bands below 6GHz.

References

[1] Draft PAR 80216-09_0068r2

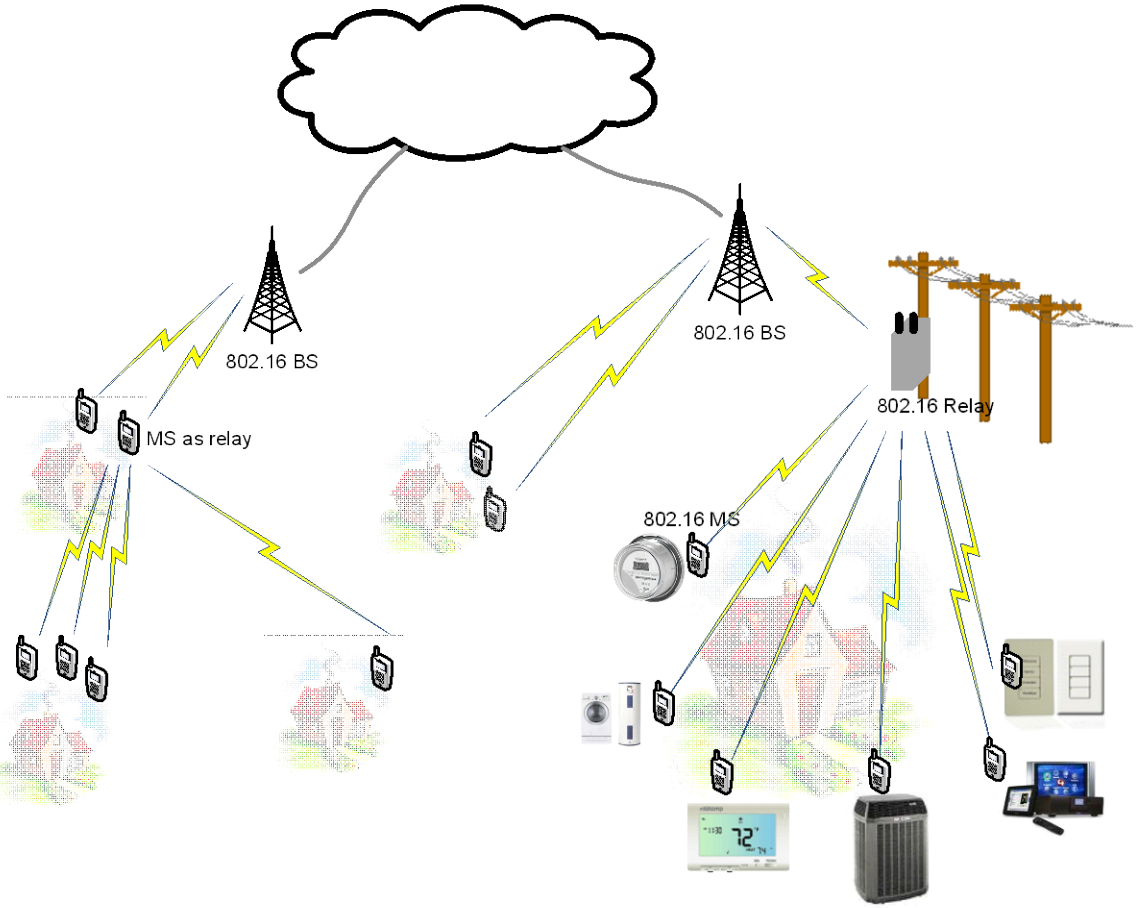

Figure 1: Example of a homogenous Smart Grid network

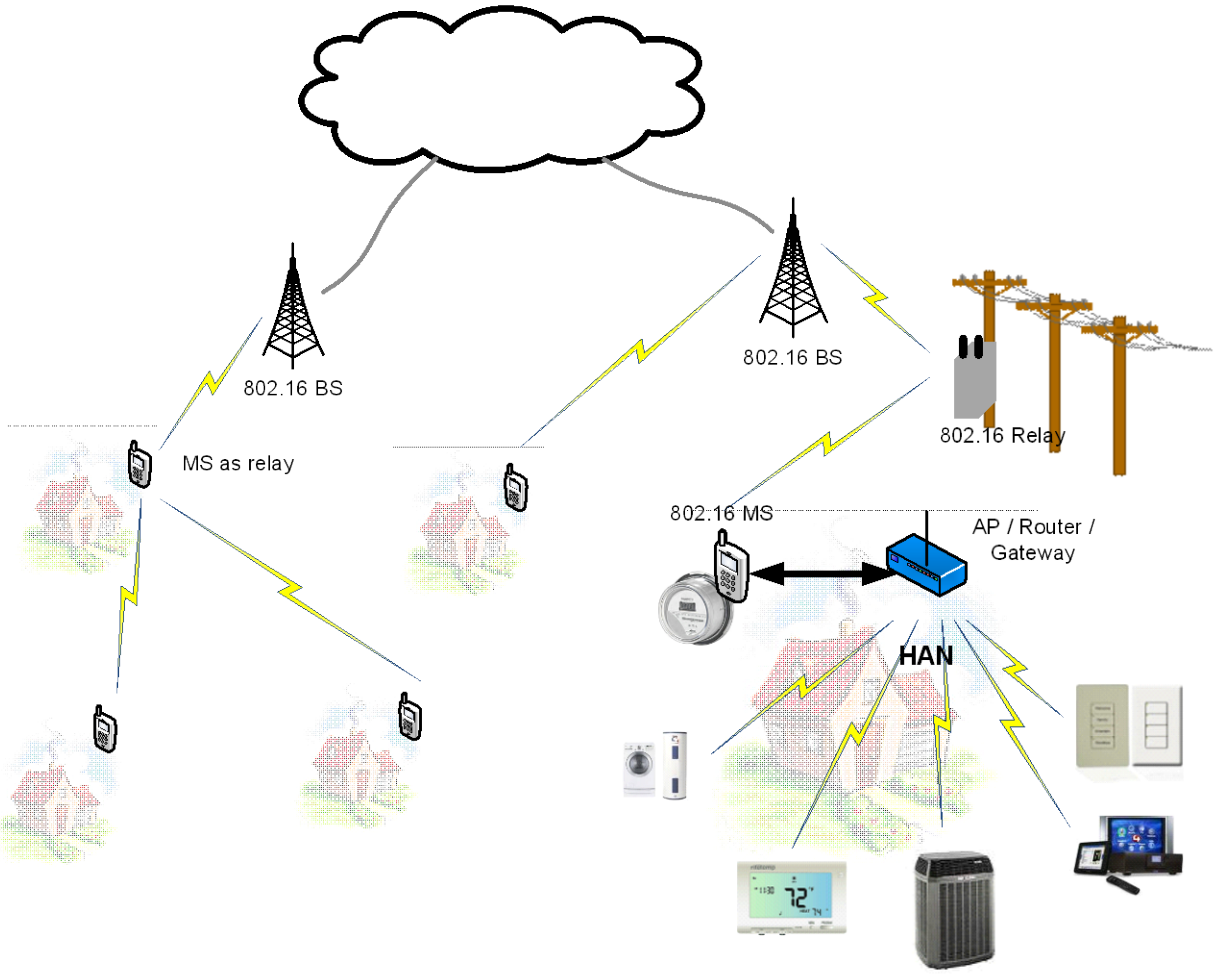

Figure 2: Example of a heterogeneous Smart Grid network