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PCT Communication Interface Questions and Issues

This document builds a framework with which to investigate the PCT communication interface, independent of whether it is 1-way or 2-way. The operational and functional requirements needed for this discussion are still under development; however the primary focus will be on the specific application of dispatching demand response (DR) for both emergency and economic events to PCT's. The first section of the document poses questions and raises issues in the communication interface definition and design which are universal to 1-way or 2-way systems. A 2-way network can enable the collection of additional customer data and value-added services, but presents additional issues pertaining to security and network topology; a section presenting issues specific to 2-way systems is presented following the primary framework. The purpose of this framework is to summarize a key set of critical questions and issues which need to be applied to each possible candidate solution.

OSI Model			Discussion Framework
Data unit	**Layer**	**Function**	
Data	Application	Network process to application	Application
	Presentation	Data representation and encryption	
	Session	Interhost communication	Network
Segments	Transport	End-to-end connections and reliability	
Packets	Network	Path determination and logical addressing (IP)	
Frames	Data link	Physical addressing (MAC & LLC)	Physical
Bits	Physical	Media, signal and binary transmission	

The framework is a compressed version of the OSI (open systems interconnection) 7-layer reference model for open communications which has been adopted by the computing industry as a standard "thought model" for designing communications and networking systems. In this implementation, it's been reduced this to 3 layers for reasons of simplicity:

- **Application**
  Issues related to exchanging data for the PCT application, including demand response functionality and security *(amalgamating the OSI Application and Presentation layers)*
- **Network**
  Issues related to topology of PCT operation and the transport of information *(in some way including OSI Session, Transport, and Network layers)*

- **Physical**
  Issues stemming from physical connection to the network *(amalgamating OSI Data Link and Physical layers)*

Universal Questions and Issues for the Communication Interface

Here is a draft list of questions and issues for each level of the interface.

Application

- **Downlink Security: What are ways in which DR data can be authenticated and possibly protected (encrypted)?**
  The solution for this interface must provide some kind of mechanism to authenticate or protect the source of the DR signal such that PCT's do not respond to "false events." It is assumed that for most emergency and economic dispatches, additional security over authentication is not needed, though some utility-specific DR programs and value-added services may require encryption.
- **Information Model**
  A common information model for DR dispatch functionality must be developed and agreed upon by the manufacturers and distribution to ensure compatibility and minimum functionality. This information model must also be translated digitally over the communication medium through a standardized protocol.

Network

- **Infrastructure, Operational, and Maintenance Costs**
  Is the infrastructure necessary to support PCT receivers at the traditional location of use (on a wall inside the residence) already existing or must it be built up or expanded? What is the cost to build or expand this infrastructure? What is the cost to operate and maintain the infrastructure 24 x 7 x 365?
- **Network Capacity**
  How much data needs to be carried by the network to support DR dispatch, system health (heartbeat messages), and other data applications (clock synchronization, pricing information, etc.)?
- **Connectivity**
  The PCT should be able to determine if it is not connected to the broadcast network so that a customer can be alerted that there is a problem. One example of this is the inability to receive a heartbeat signal.
- **Error Detection and Correction**
  How are errors in data transmission detected and corrected? What is the overall strategy for error detection and correction (e.g. In 1-way applications is it OK if say 1% of the PCT's do not receive the correct data transmission? Will there be rebroadcasts and multiple attempts to communicate with all PCTs?)
- **Membership: How could various manufactured appliances and devices establish membership?**
  The PCT needs to understand its membership to parent entities to obtain a desired granularity of demand response. This membership information can be accounted

for through network addressing or some kind of addressability information embedded in a universal broadcast. The levels of membership, to increasing precision, are listed:
  - With the ISO
  - With the Utility
  - With program enrollments (various DR and load control programs offered by the utilities and munis for economic response)
  - With the customer (AMI/EMCS system)

Physical

- **Frequency Band and Channel Plan**
  For a wireless system, a frequency band must be chosen within licensed (i.e. AM radio, FM radio, television, PCS communications, paging) or unlicensed (i.e 900 MHz, 2.4 GHz, 5.8 GHz) bands. The bands will have different attenuation characteristics and sources of interference, each addressed in separate sections below. The unlicensed ISM bands for wireless communication are limited to a fixed number of channels, which must be distributed among the broadcast infrastructure in 1-way applications. Though the primary 1-way candidates already leverage existing infrastructure which has already been built to address channel plan issues, there are still questions to be answered. For example, in the FM scenario, the minimum number of carrier channels per geographic region must be considered, and then the PCT receiver must be able to identify the best channel to use.
- **Radio**
  - **Cost**
  - **Overhead (hardware and software burden to the core t-stat)**
  - **Data Rate**
  - **Receive Sensitivity**
    The receive sensitivity specifies how faint a signal (low in power) a receiver can successfully receive a signal. The smaller the receive sensitivity the better. The receive sensitivity, combined with knowledge of the transmitter strength, gives a general indication of radio range.
  - **Range**
    What is the maximum free-space radio range (signal power falls off as R^2)? What is the practical radio range in the target environment, given sources of signal attenuation such as concrete or other building materials (signal power falls off as R^4 in urban outdoor environments, or even faster within buildings)? What is the standard deviation signal power vs. distance in the target environment?
- **Power-use (accounting for duty-cycle assumptions)**
  Power use will depend on network configuration as well as the receiver hardware. Under certain scenarios for powering on the receiver, what is the expected average power use for the receiver?
- **Antenna**
  A practically realizable, inexpensive antenna at the correct frequency and with the required bandwidth (including manufacturing tolerances) will be needed to make

the system work. As the frequency of the signal increases, the wavelength, and consequently ideal antenna size, decreases. Another variable is the antenna gain that is needed to make the system work properly. In general gain decreases with size, from +6 dB for a half-wavelength antenna to perhaps -10 to -20 dB for an antenna which is a tenth of a wavelength.

- **Noise, Reflections, and Interference**
  Sources of electromagnetic interference and signal reflections will affect the signal-to-noise ratio. Reflections of a radio transmission can lead to multiple signals arriving at the receiver with some level of multi-path delay between them. This can lead to inter-symbol interference, which can impair radio operation. However, both the FM broadcast and the IEEE802.15.4 radio systems are quite accommodating of multi-path propagation and delay spread. Common sources of electromagnetic interference, such as cordless phones, microwave ovens, Wi-Fi radio transmitters, and I-pods with FM converters can also be cause for concern. A noise rejection scheme can be chosen – frequency hopping spread spectrum vs. direct sequence spread spectrum vs. ultra wideband – to improve the system performance. How will the PCT know it is experiencing radio interference, and how will it notify the user?

Additional 2-Way Specific Issues

The draft list of questions and issues documented in this section arise from the added complexity of 2-way systems.

Application

- **Uplink Security: In 2-way applications, what are the ways in which data collected from PCTs are validated and protected from malicious spoofing, are kept private and protected from data theft?**
  Whereas downlink DR data represents “one-to-many” transmission of information from a single (trusted) source, uplink radio transmissions from PCTs over a mesh network represent “many-to-many” transmissions of information that may need to be validated at each point of entry into the communication network. The additional (above acknowledgement) data transmitted back to the distribution utilities, as desired to support the business cases being considered, adds considerable complexity to security and privacy issues. Privacy laws will have a considerable influence on the system design for transmission of customer use data. For example, FERC regulation for any controllable load amount greater than 300 MW mandates a certain level of data protection.

Network

- **Network Capacity**
  How much data needs to be carried in 2-way (uplink as well as downlink) applications?
- **Network Topology**
  Is the network topology a star, a structured mesh, an ad-hoc mesh, or other? Are successful data transmissions dependent on the relay of data packets through secondary radio nodes? If so, are these nodes part of the communication

infrastructure, or not? How are secondary relay nodes powered? How does the relay of data packets affect battery life?

- **Error Detection and Correction**
  How are errors in data transmission detected and corrected? Are acknowledgements of correct data transmission needed (in 2-way applications)? Will the PCT make multiple attempts to transmit to the gateway?

Physical

- **Access Method**
  Is the radio access method (for 2-way applications) based on reserved capacity (e.g. time slots), or is random access based on contention (and the possibility of packet collisions) employed? How does the access method affect network capacity, overhead in data transmission, and the likelihood of successful data transmission?
- **Radio**
  - **Transmit Power**
    In a 2-way application, the radio will consume a considerable amount of power for transmission as well. Generally, the power to the transceiver in wireless nodes is held constant, while the duty cycle is adjusted to meet the power budget.
  - **Range**
    Given the transmit power and antenna gain, what is the maximum range for uplink transmissions?
- **Power-use (accounting for duty-cycle assumptions)**
  Power use will depend on network configuration as well as the receiver hardware. Under certain assumptions for data transmission, what is the expected average power use for uplink transmissions?
- **Channel Plan**
  How many separate non-overlapping radio channels can be used to create subnetworks (particularly in 2-way applications)? What geographic separation is needed in order for radio channels to be reused in different regions?