The ANSI C12 protocol suite - updated and now with network capabilities

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***Abstract*--For ten years, the utility industry has been using optical port communications, defined by ANSI C12.18, and telephone modem communications, defined by ANSI C12.21, to get metering data, defined by ANSI C12.19, from the field to the back office. While the two communication protocol standards have been employed to great success, missing was a standard method for using true "network" communications for exchanging this data. Recent work has completed ANSI C12.22, a standard for interfacing to data communication networks, as well as updating the optical port and modem communications standards. This set of standards offers the industry an open and comprehensive "protocol suite" to transport the newly revised data standard, ANSI C12.19. This paper focuses on how utilities can best benefit from deploying technologies that meet those standards, in particular the newly developed ANSI C12.22 networking standard, as they begin to build advanced metering infrastructures. In particular, utility requirements being refined by OpenAMI Task Force are matched against the offerings from the ANSI protocol suite.**

***Index Terms*—Electricity metering, communications, networks.**

I. Nomenclature

AMI – Advanced Metering Infrastructure. Typically, this is inclusive of a "smart meter," a communications infrastructure, and software to manage the system.

AMR – Automated Meter Reading. Typically this is inclusive of a conventional meter, often electro-mechanical, coupled with a communications infrastructure, often one-way, and software to manage the system.

C12.18 – Used to refer to ANSI C12.18, the optical port and PSEM standard for metering.

C12.19 – Used to refer to ANSI C12.19, the data structure (tables) standard for metering.

C12.21 – Used to refer to ANSI C12.21, the modem and PSEM standard for metering.

C12.22 – Used to refer to ANSI C12.22, the network protocol standard for metering.

EPSEM – Extended Protocol Specification for Electronic Metering

HTML – Hypertext Markup Language

HTTP – Hypertext Transfer Protocol

PSEM – Protocol Specification for Electronic Metering

Smart Meter - A meter designed to support various applications beyond monthly billing. Typically, smart meters are solid state devices that support a wide variety of measurements beyond a traditional dial read, as well support for integration with in-home devices, and command and control applications.

II. Introduction

FOR many years, meter data collection has been considered to be a very hands-on activity. Whether manually performed, or done via the myriad automated meter reading (AMR) technologies, personnel may be required to visit each site to collect the data, and, when the meter allows it, perform any reconfiguration desired. Most data collection systems are built and optimized with the goal of minimizing visits to each meter, as each visit adds to the labor costs incurred by the utility. Historically, to minimize device cost many of these systems employ a one-way architecture, pushing data from the meter to the devices used to collect the data.

When getting a large amount of meter data and configuring large volumes of meters was still considered a novel concept, industry partners developed two ANSI protocol standards, ANSI C12.18 [1] and ANSI C12.21 [2] to facilitate deployment of multi-vendor solutions by utilities. Both standards use a session-based protocol, the Protocol Specification for Electricity Metering, or PSEM, and a physical connection, the ANSI Type 2 Optical Port and any serial connection, respectively. Certainly, the cellular telephone industry has in recent times rendered the one-way architecture less desirable. The ubiquity and improving reliability of cellular coverage, along with the desire to avoid "pulling wire" to connect individual devices, has certainly changed the marketplace for meter information gathering. While a certain amount of equipment still needs to be deployed, the physical connection from the meter to the utility can be replaced.

Concurrently, the utility industry has found itself on the public stage, having to explain large-scale outages and escalating prices to angry customers. While a one-way AMR solution may provide a "cheap read," it does not provide facilities to enable demand response, load control, or "smart grid," programs. Increasingly, utilities are looking to these sorts of programs to as a tool to address issues of system reliability, supply constraints, capital investment, and environmental concerns.

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This article will discuss the advantages of using devices conforming to a forthcoming standard, ANSI C12.22 [3], to meet the data collection needs of today's utilities within what could be considered an advanced metering infrastructure (AMI): full two-way communications to every electricity meter for reading and configuration. These needs have been enumerated by a group known as UtilityAMI through publication of their "high-level requirements".

III. Benefits of ANSI C12.22

With the development of C12.18, C12.19, and C12.21 it became possible to implement standard methods of communicating with meters over optical probes or telephone lines. These standards have been widely adopted by the industry, and are basic requirements specified in new meter tenders; however, they have tended to be specific to meters used for recording usage from high consumption, high value customers, such as large commercial and industrial facilities. C12.21, C12.18, and C12.19 are widely used in the commercial and industrial (C&I) meters, but deploying modem lines for meter reading of residential meters, or using an optical probe is not economically practical.

As a result, a wide variety of AMR solutions have flourished, each endeavoring to improve the cost of meter reading. Solutions have been built around a variety of proprietary RF, PLC, public carrier RF, two-way paging, and other communications solutions. Regardless of the communications technology in use though, each of these solutions has remained a closed, proprietary system with no interoperability between vendors. Utilities are forced to choose a single system, and, typically, maintain it from a single vendor.[1]

C12.22 is designed to address this. By creating a standard protocol for network communications, irrespective of the underlying transport, it is possible for a utility to implement an AMR or AMI solution that is not locked to a single vendor, or a single technology.

At its core, the C12.22 standard defines two things: A transport independent application level protocol for exchanging data between nodes, and a physical and data link protocol for linking meters and communication technology. Like the C12.18 and C12.21 standards, C12.22 is designed to move C12.19 table data using PSEM messages.

PSEM, as defined by ANSI C12.18 and ANSI C12.21, is a session-based protocol wherein both parties to the communications are able to issue requests and responses. In some cases, the responses are mandatory, and lost responses may result in a reset of the communications link. Whether over the optical link (ANSI C12.18) or over a modem (ANSI C12.21), the communications are relatively secure. For the former, the connection path is relatively short (in the scale of millimeters) and necessitates a specific piece of equipment, known commonly as an optical probe, to enable the communications. For the latter, the use of the public switched telephone network obviated more security. The standard provides both authentication and encryption mechanisms to thwart interception of the information.

C12.22 extends PSEM with EPSEM, or the extended protocol specification for electronic metering. EPSEM adds the ability to chain commands, as well as several new commands for managing communications over a shared media with multiple nodes.

A good parallel for the relationship between C12.22, C12.19, and the underlying transport, is HTTP and HTML. HTTP is an application protocol. While it is regularly implemented over TCP/IP, there is no particular need to use IP to deliver it. HTTP defines a series of commands for exchanging HTML data between two nodes without regard to the underlying transport. Similarly, C12.22 provides a mechanism for exchanging C12.19 data between two nodes, without regard for the underlying transport. In the case of HTTP, typically a TCP session is established, and then the protocol is used to exchange data. This of course relies on IP addressing. In the case of C12.22, an integral logical addressing scheme based on ACSE is provided.

By also defining a physical transport and data link protocol between meters and communications modules, the C12.22 standard makes it possible for meters and communications technology to mixed and matched. The current state-of-the-art requires tight integration between meter and communications vendors. A communication vendor wishing to create a module for each of the four major U.S. meter manufacturers would have to work with each one to design a module for their specific device. In many cases, they will have to design a different module for each device from a given manufacturer. Similarly, a new entrant into the meter market needs to persuade an established communications vendor to support their device, if they want to enable AMR. This continued point-to-point integration prevents promotes vendor lock-in and increases utility costs. Because C12.22 defines exactly how a meter and a communications device will interface, as vendors adopt the standard it should allow much greater interoperability, as well as flexibility for utilities implementing AMR and AMI systems.

IV. UtilityAMI

UtilityAMI [4] is first a utility forum for advanced metering infrastructure (AMI) and demand response (DR) specification development. The members are charged with determining high level policy statements for use in efficient requirements and specification development. Participation in UtilityAMI is open to any individual or organization, while membership is restricted to any UCA International Users Group [5] member, with voting privileges restricted to utility members of that user's group.

One of the members released to that group documents related to their internal AMI project, including their

[1] Cross licensing arrangements, patent expirations, and regulatory requirements have meant that some AMR technologies are available from multiple vendors. This is generally the exception, and not the rule. Most communications systems can be purchased from a single vendor, though often they can be fitted to meters from a variety of different manufacturers.

preliminary AMI requirements, their metering requirements specification and their metering and communications capability framework. Based on these, the membership developed a generic set of "high-level requirements" [6] that was balloted and approved for release. The intent of publishing these requirements is to minimize the uncertainty for both utilities and vendors with respect to AMI systems. Vendors are advised to design product(s) with the requirements in mind, and utilities are advised to use the requirements to assist in specifying product(s) desired.

Having completed work on the requirements, the members agreed to address the following policy issues related to AMI and DR (in order of priority) [7]:

- Glossary and common language framework
- Modular meter interface
- AMI network interface
- Consumer interface
- Back office interface
- Security

Once each policy issue is addressed by UtilityAMI, another group, known as the OpenAMI Task Force [8], works to recommend (or develop) relevant technical solutions to meet the issue. A technical solution might range from a list of recommended standards to a new technical specification that products should meet to be considered viable candidates for deployment. Participation in OpenAMI is available to any membership or organization, with voting privileges restricted to UCA International Users Group members.[2]

V. UtilityAMI Requirements and ANSI C12.22

There are eighteen high-level requirements defined by UtilityAMI. It should be noted that these are for an *advanced metering infrastructure*, in which a device that contains metrology and communications capability plays a small part. Each of the requirements will be addressed from the "*meter*" standpoint only; the complete "*infrastructure*" discussion is outside the scope of this paper.

A. Standard Comms Board Interface

There is a physical interface defined in ANSI C12.22 that, when combined with the operational capabilities of the meter and communications board, would address the following "expected features": physical (interpreted to be the connector between the meter and communications device) and environmental specifications (it is worth pointing out that most "ANSI" meters must meet the accuracy and performance tests in ANSI C12.1 [9] or ANSI C12.20 [10]), electrical specifications, protocol specifications, and automatic identification of communications board to meter and network. The outlying feature specified in the Utility AMI requirements would be "compatibility with existing form factors", which has been interpreted to be a three-dimensional space common to all ANSI meters wherein the communications board would reside.

B. Standard Data Model

ANSI C12.22 is intended to be used to transport meter data as defined by ANSI C12.19, the *Utility Industry End Device Data Tables* [11], [12]. This standard has been in existence since 1997 and is currently under revision. A meter and communications board combination exchanging data in this format with any other system would meet two of the four "expected features": usable over multiple media, and the guidelines for extension. However, the ANSI standards are weak in the area of defining interoperability requirements, as they are by definition toolkits to perform the actions, not a user's guide of how to use the toolkits in an identical manner as another. Finally, while not perfectly meeting the multiple protocol feature *a priori*, the forthcoming rules for translating the ANSI table data into Extensible Markup Language (XML) format facilitates quick translation between data formats by back-end utility systems.

C. Security

A complete implementation of ANSI C12.22 security and authentication services, combined with the event logger of ANSI C12.19, would allow a utility to meet all of the "expected features." This includes encryption, authentication, credential management (through the security tables in Decade 4 of ANSI C12.19), intrusion detection, logging and auditing of all changes to data and configuration. These standards can meet the UtilityAMI requirements for all parts of the network as well as the meter maintenance access port. Securing each part of the entire infrastructure involves much beyond the scope of these two standards, but from the device standpoint, the tools are available to meet the requirements.

D. Two-way Communications

This is a network-focused requirement as defined by UtilityAMI. Assuming a meter and communications device support two-way communications, nothing in ANSI C12.19 or C12.22 preclude meeting the "expected features" of sufficient bandwidth for remote downloading of configuration and firmware, extensibility, security, interference with other networks, or providing on-demand meter reads.

E. Remote Download

The "expected features" of this requirement are being met with deployed meters in today's market – the key difference being that a site visit to perform the programming or a dial-up modem is required. The ANSI C12.19 and C12.22 standards provide the means to update meter settings and configurations, to change security credentials and to perform firmware modifications, over the network.[3] Because C12.22 and C12.19 are transport independent, products build to support these standards should allow firmware updates to meters

[2] OpenAMI allows all UCA International Users Group members voting privileges, as opposed to UtilityAMI which is restricted to utility members of UCA international.

[3] The ANSI C12 protocol suite does not, as of this writing, define a standard way of performing a firmware update. It does however provide a uniform way of exchanging data structures, which allows features such as remote firmware updates to be performed through the protocol.

regardless of the transport, provided it has sufficient bandwidth. For the communications device themselves, it will be up to the communications device vendors to allow for this for their modules, though they too can take advantage of C12.19 and C12.22.

F. Time-of-Use Metering

Assuming the meter and communications device support this requirement, ANSI C12.19 and C12.22 provide for an implementer to meet the "expected features" of remote programming of intervals, remote programming of rates and billing periods, time synchronization, and time and date stamping of measurements and logs.

G. Bi-directional and Net Metering

This requirement and set of "expected features" is related to metering device hardware. Despite that, it is possible to provide for the features of delivered and received energy consumption, demand data and interval data if the meter device supports them, in ANSI C12.19 table format over ANSI C12.22.

H. Long-term Data Storage

The "expected features" of this requirement are related to metering and "concentrator" hardware; as such, they are unrelated to either a protocol or data model standard. The minimum requirement of two channels of data for a time period of forty-five days is not an onerous one. However, few meters in production have field or meter shop expandable memory (interpreted here as expansion-slot based as in a computer). Implementing this requirement may be challenging based given the environmental concerns typically faced by an electric meter. The other two requirements are related to data concentrators and will not be addressed here.

I. Remote Disconnect

The second revision of ANSI C12.19 contains a Decade dedicated to load control and pricing control parameters. This capability would be available to devices employing the ANSI C12.22 services. It would be up to individual vendors to meet the "expected features" by integrating the disconnect switch into the meter (or under the cover), put a switch setting on the display and transmit confirmation of any load control commands via the ANSI C12.22 services.

J. Network Management

Though an obvious beyond-the-meter requirement, most meters and communications devices offer the ability to meet the "expected features" of remote self-tests (for a meter, a self-read), statistics gathering (for a meter, logging parameters), spontaneous trouble alarms (if supported by the meter), remote link enabling and disabling (an expected feature of any two-way communications system), periodic gathering of event logs (when in the meter), auditing of time synchronization (all meters can configure and report the time), and detailed daily reports. Most advance meters offer the ability to log a suite of parameters and configurations that would support network management, without performing that function on their own. In many cases, the ANSI C12.19 data and C12.22 protocol already allow for most of these functions.

K. Self-healing Network

This requirement is network focused. Redundant signal paths, switchover algorithms, traffic balancing, and assurance that 98% of devices respond to commands are system design issues, not meter and communications device issues.

L. Home Area Network Gateway

This is one area that is not directly addressed by the ANSI standards under consideration in this paper as is a topic that is out of scope of those standards. It is worth noting, however, that C12.19 is designed to be fully extensible with additional data structures. With C12.22 used as a transport for the C12.19 data, information can be moved very efficiently between a utility system and a meter, for use in a meter-based home gateway interface, regardless of the physical transport to the meter.

M. Multiple Clients

While system focused, meters and communications devices built to ANSI C12.19 and C12.22 standards would fit into a system that performs on-demand and off-cycle polling within the authentication and authorization needs of the utility. C12.22 requires that all devices that are part of the C12.22 network, be they meters, utility systems, or devices in between, have a C12.22 address, or ApTitle. Communications on a C12.22 network can be between any C12.22 devices, easily allowing multiple hosts and multiple clients. Meters and communications devices typically have a unique serial number, which could be used as part of an individual network address. There are provisions in C12.22 both for individual addressing of those devices, and for network independent multicast and broadcast communications. Finally, neither standard would limit reading system(s) from creating arbitrary aggregated meter groups for non-predefined purposes; in fact, with integral multi-cast support within the protocol, they provide tools to enable such arbitrary aggregation and addressing.

N. Power Quality Measurement

If the meter has the "expected features" related to power quality such as the ability to measure voltage, total harmonic distortion, sags, swells, interruptions, harmonics, phase voltage RMS values, and incorporates close to real-time monitoring of the delivery point, there is an entire Decade in ANSI C12.19 devoted to properly formatting the data for transmission using ANSI C12.22.

O. Tamper and Theft Detection

If the meter has the "expected features" of inversion, removal and activity detection and blink counts, there are provisions in ANSI C12.19 to properly format the data for transmission using ANSI C12.22.

P. Outage Detection

Most meters are capable of detecting outages on a perphase basis, generating outage reports, and providing the outage interval and restoration time. The use of ANSI C12.19 and ANSI C12.22 does not preclude the system from becoming aware of outages or providing that data. While not providing a “standardized open protocol interface to outage management systems”, the meter data collection system could be configured to meet that need.

Q. Scalability

The meter and communications device pair would not inhibit proper scaling of the AMI system as by definition in the relevant portions of ANSI C12.22, the concepts of modularity, distributed processing (at the meter and communications device level), automatic detection of new additions (through the standards’ services), configurable resource limits (to what the devices are capable) are taken into account.

R. Self Locating

If the meter has the capability of determining its latitude and longitude, or its nearest communication node, there are provisions in ANSI C12.19 to properly format the data for transmission using ANSI C12.22.

VI. Conclusions

The C12.22 protocol has been many years in the making. It is built on established encoding and data exchange mechanisms, such as ASN.1 and ACSE. This basis may not be as exciting as some of the core technologies used in more general IT protocols, but they are proven in the telecommunications space, and well suited to low cost devices such as meters. C12.19 and C12.22 can be implemented on devices with relatively small amounts of microcode and processing power, including machines with as little as 64k of code space. This is important to consider when the scope of a full system roll-out of residential meters may involve millions of devices. Protocols with greater overhead or processing power needs may not be cost effective for general deployment.

C12.22 provides mechanisms to meet many of the UtilityAMI requirements. As a standard, it is available in draft form now, and should be officially published in early 2007. By adopting C12.22, vendors can provide the interoperability sought by UtilityAMI today. By demanding C12.22, utilities and regulators can reduce vendor lock in, and ensure a much more efficient and competitive marketplace for metering and communications technologies.

There are some drawbacks to the C12.22 protocol. Clearly, no protocol is perfect. There are places where the standard is open to interpretation, and it will take time to work out full interoperability between C12.22. This could be used as a reason to delay implementing or requiring C12.22; however, this will just mean that another generation of meters and communications technology will deployed to the field, without the benefit of open standards and the interoperability they afford. By adopting C12.22, the industry can make the commitment to open standards between meters, communications devices, and data collection systems, and then work within the C12 committees to further refine and improve those protocols. Wide-scale implementation of C12.22 will bring about many of things identified by the UtilityAMI working group as “expected features” of an Advanced Metering Infrastructure.

VII. Appendix I: ANSI C12.22 Services

This appendix provides a summary of the services (command set) available to implementers of the ANSI C12.22 standard.

Table III
C12.22 Node to C12.22 Network Segment Application Layer Services

Name	Response Type
Identification Service	Complex*
Read Service	Complex
Write Service	Complex
Logon Service	Simple
Security Service	Simple
Logoff Service	Simple
Terminate Service	Simple
Disconnect Service	Simple
Wait Service	Simple
Registration Service	Complex
Deregistration Service	Simple
Resolve Service	Simple
Trace Service	Simple

*Complex refers to a response containing more than a simple acknowledgment.

Table IV
C12.22 Device to C12.22 Communications Module Transport Layer Services

Name	Response Type
Negotiate Service	Complex*
Get Configuration Service	Complex
Link Control Service	Simple
Send Message Service	Simple
Get Status Service	Complex
Get Registration Status Service	Simple

*Complex refers to a response containing more than a simple acknowledgment.

Appendix II: ANSI C12.19 Decades

This appendix provides a summary of the data table set and procedures available to implementers of the ANSI C12.19 standard.

Table I
ANSI C12.19 Tables

Decade Number	Name	Number Of Tables
0	Configuration Tables	9
1	Data Source Tables	8
2	Register Tables	9
3	Local Display Tables	5
4	Security Tables	6
5	Time-of-Use Tables	7
6	Load Profile Tables	8
7	History and Event Logs	10
8	User Defined Tables	10
9	Telephone Control Tables	9
10	Extended Source Tables	4
11	Load Control and Pricing Tables	9
12	Network Control Tables	8

Decade Number	Name	Number Of Tables
13	Relay Control Tables	7
14	Extended User Defined Tables	4
15	Quality of Service	9
16	One Way Devices	5

TABLE II
ANSI C12.19 PROCEDURES

Number	Name
0	Cold Start
1	Warm Start
2	Save Configuration
3	Clear Data
4	Reset List Pointers
5	Update Last Read Entry
6	Change End Device Mode
7	Clear Standard Status Flags
8	Clear Manufacturer Status Flags
9	Remote Reset
10	Set Date and Time
11	Execute Diagnostics
12	Activate All Pending Tables
13	Activate Specific Pending Tables
14	Clear All Pending Tables
15	Clear Specific Pending Tables
16	Start Load Profile
17	Stop Load Profile
18	Log In
19	Log Out
20	Initiate an Immediate Call
21	Direct Load Control
22	Modify Credit
23	Register
24	Deregister
25	Network Interface Control
26	Exception Report
27	Clear Pending Call Status
28	Start Quality Of Service
29	Stop Quality Of Service
30	Start Secured Registers
31	Stop Secured Registers

VIII. REFERENCES

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IX. BIOGRAPHIES

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