IEEE Utility Communications Architecture (UCA) applies mainstream standard Ethernet

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Abstract. The Utility Communications Architecture (UCA™) is a standards-based approach to utility communications which provides for wide scale integration at reduced costs, and which solves many of the most pressing communications problems for today's utilities. The UCA is designed to apply across all of the functional areas within the electric, gas, and water utilities. These functional areas include customer interface, distribution, transmission power plant, control center, and corporate information systems. The UCA includes detailed object models, which defines the tag, format, representation, and the meaning of utility data. This modeling effort goes far beyond the scope of any other utility communications approach, and provides for an unprecedented level of multi-vendor interoperability applicable in most industries.

1 Introduction

Worldwide, electric utility deregulation is expanding and creating demands to integrate, consolidate and disseminate information quickly and accurately between and within utilities. Utilities spend an ever-increasing amount – estimated $2 billion to $5 billion dollars a year in the USA only – for voice and data communications. There are already strong pressures to find ways of reducing operating costs to improve the utility earnings. In response to this need, IEEE has published a complete set of communication protocols. The international utility industry, comprising Electric, Gas, and Water utilities, is a key participant in the development and use of IEEE standards, along with the manufacturers of equipment conforming to the developed standards. These utilities rely heavily on standards in many areas including: electrical, mechanical, computers hardware, and computer software.

Several years ago, the members of both IEEE and the Electric Power Research Institute (EPRI, Palo Alto, USA) identified the need to understand and properly implement open communication architectures. This need arose from the rapid expansion of interconnection technologies and the consequent demand for better exchange of information between various elements of the power delivery system, the utility's customer service and support staffs, and their customers.

In their role as research and development arm of the international electric utility industry, EPRI funded a research and development effort to create the Utility Communications Architecture (UCA™). ISO, IEEE, and other related communication standards (e.g., 10/100 Mbit/s Ethernet, ISDN, MMS – ISO 9506) were assembled to define UCA which its member utilities can use in meeting their communications needs. EPRI developed an assessment of functional and communications needs for the industry by area, and developed a methodology to map these needs to established and emerging standards developed by organization such as the IEEE. The result is a specification that points to standards that could be used to accomplish work at a utility in an 'open' fashion.

Since the standards comprising UCA come from many areas such as the electric industry, the gas industry, the water industry, the communications industry, and the computer industry, EPRI believed that an IEEE Standards Coordinating Committee (SCC) is the best vehicle to facilitate coordination among all of these groups. Therefore, IEEE set up a new IEEE SCC, the SCC 36 (Utility Communications Architecture, UCA) whose charter is to coordinate the on-going work of refining and expanding the UCA communications protocols, and to ensure that these protocols are developed and/or accepted as international standards through the IEEE, the International Electrotechnical Commission (IEC), and other standards organizations as appropriate. The SCC 36 has unanimously decided to publish the UCA Version 2 specification as IEEE Technical Report (IEEE TR 1550) in July 1999.

2 The Utility Communications Architecture (UCA)

The Utility Communications Architecture (UCA) is a standards-based approach to utility communications which provides for wide scale integration at reduced costs, and which solves many of the most pressing communications problems for today's utilities. The UCA is designed to apply across all of the functional areas within the electric, gas, and water utilities. These functional areas include customer interface, distribution, transmission power plant, control center, and corporate information systems. It is important to note that UCA is an architecture, rather than a simple, protocol. The UCA Version 2.0 incorporates a family of basic communications protocols to meet the requirements of a wide range of utility environments. The selection and organization of these protocols has been designed to provide great flexibility in choosing the appropriate technology to meet a utility's price/performance criteria, while maintaining consistency at the device and data level to reduce integration and vendor product costs. In addition, the UCA includes detailed object models, which defines the tags, format, representation, and the meaning of utility data. This modeling effort goes far beyond the scope of any other utility communications approach, and provides for an unprecedented level of multi-vendor interoperability.

The UCA documents currently specify a set of existing international standards which can be applied to specific communications architectural requirements in the utility industry. Information in the documents can be used to define and implement a wide variety of standards-compliant communications systems such as those required to support Distribution Automation, Demand Side Management, Substations and Control Systems, Power Plant Automation, and Customer Interfaces.

The UCA documents comprise the following documents:

Common parts

- Introduction to UCA
- UCA Profile Specification

Modeling and communication for intelligent devices

- Common Application Service Models (CASM),
- Generic Object Models for Substation and Feeder Equipment (GOMSFE),
- Customer Interface Device Models (under preparation)
- Power Plant Device Models (under preparation)

Real-time data exchange between control centers

- IEC 60870-6-503: TASE.2 Services and Protocol
- IEC 60870-6-802: TASE.2 Object Models
- IEC 60870-6-702: TASE.2 Application Profile

The common parts and the parts for modeling and communication for intelligent devices have been incorporated in the IEC TC 57 committee drafts of the series IEC 61850 (Communication networks and systems in substations) published in 1999. The standards for real-time data exchange between control centers (TASE.2 – Telecontrol application service element 2) have been published as international standards in 1997.

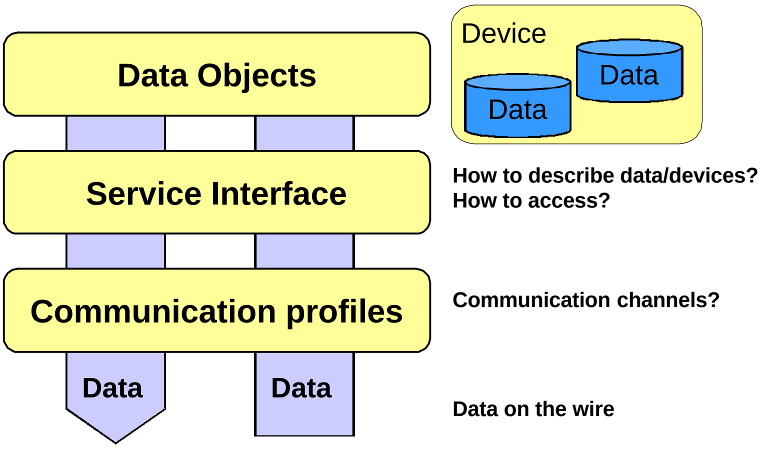

Fig. 1. The three levels of UCA

The UCA comprises the data object models (forming the highest level), the service interfaces to these models (defining, retrieving, reporting, and logging of process data, controlling devices, file transfer etc.), and the communication profiles (see figure 1).

3 The UCA Communications profile

Similar to current Internet solutions, UCA provides a network solution to interconnect data sources within and between utilities.

Ethernet was chosen as the main solution because of its:

- Market dominance;
- Plentiful, low-cost hardware, such as bridges and routers; and a
- Scalability from 10 and 100 Mbit/s, with 1 Gbit/s becoming available soon.

Figure 2 lists the complete communications architecture of UCA. UCA provides TCP/IP as well as full ISO/OSI seven layer solutions. For specific requirements a third block shows the reduced stack variants.

	Full 7 CO	WAN 7 CL	Modified 7 CO	Reduced Stack CO	Reduced Stack CL	LAN-Based FAIS	LAN-Based ** Ethernet	TCP/IP RFC 1006	TCP/IP RFC 1070	TCP/IP RFC 1240
Application	MMS ACSE	MMS CL-ACSE	MMS ACSE	MMS ACSE	MMS CL-ACSE	MMS	MMS ACSE	MMS ACSE	MMS ACSE	MMS CL-ACSE
Presentation	Presentation	CL Pres.	FastByte Pres.					Presentation	Presentation	CL Pres.
Session	Session	CL-Session	FastByte Session					Session	Session	CL-Session
Transport	TP4	CLTP	TP4					TP0 TCP	TP4 CLNP UDP	UDP
Network	CLNP	CLNP	CLNP			Auxiliary		IP	IP	IP
MAC Data Link	LLC1 ADLC FT3 or UCA 1	LLC1 ADLC FT3 or UCA 1	LLC1 ADLC FT3 or UCA 1	LLC1 ADLC FT3	LLC1 ADLC FT3 or Ethernet	LLC3 802.4 Token Ring	LLC3 ADLC FT3****over*** Ethernet	Ethernet SLIP, PPP (typical)	Ethernet SLIP, PPP (typical)	Ethernet SLIP, PPP (typical)
	7 Layer			3 Layer				TCP/IP		

Fig. 2. UCA Communications architecture

To allow data access from any device, anywhere, UCA adapted International Organization for Standards (ISO, Geneve, Switzerland) Open Systems Interconnect (OSI) standard and Transport Control Protocol/Internet Protocol (TCP/IP). Protocols for the OSI's seven-layer are implemented. The most important protocol, the application layer, is built on the services of the Manufacturing Messaging Specification (MMS, ISO 9506).

4 Common Application Service Model (CASM)

The UCA Common Application Service Model (CASM) provides a common set of communication functions for data access, reporting, logging, control applications and related support. The use of a common set of services allows for 1) isolation of the models from service and communication details, 2) a high level of application interoperability, and 3) reduced integration and development costs through the use of common mechanisms for data access and communication establishment. The CASM services are abstract and may be mapped into any number of existing communication application standards. MMS (ISO 9506) is the service specification of choice and mapping of CASM into MMS is included in the UCA document

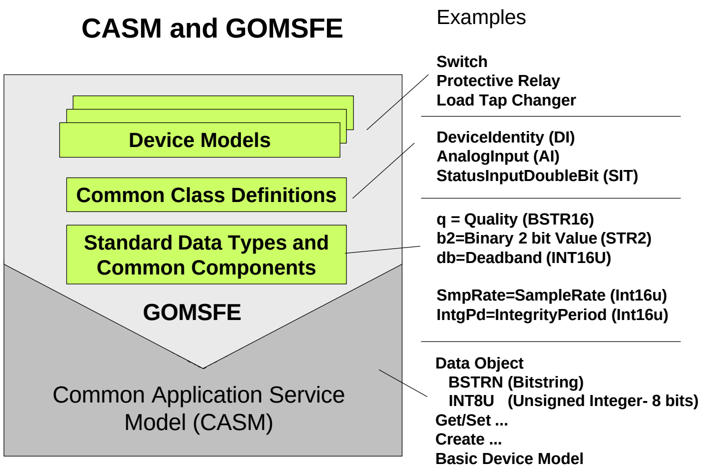

Fig. 3. UCA layering

As depicted in figure 3, the CASM provide services directly to the GOMSFE models.

5 Generic Object Models for Substation and Feeder Equipment (GOMSFE)

One of the primary tasks has been the development of models for protective relay functionality along with all other anticipated IEDs in the substation. The development of these IED models is known as the Generic Object Models for Substation and Feeder Equipment (GOMSFE). Starting with a base set of models, each of the relay vendors has added draft models for an additional one or two functions, which brought the total to 13 models. These 13 protective relay function models have been reviewed in depth, and two basic building block models were developed (Basic Relay Object and Basic Time Curve Object). The existing models have been reworked to use the basic building block objects, and add extensions as necessary. It was concluded that an additional 23 relays could be modeled using the basic building blocks.

The most important GOMSFE device models are listed below. These models define some 2000 tagged information like vendor name. software revision, switch position status, current phase A measurement, or control a switch.

Exerpt of the UCA device models:

- Generic Input/Output
- Measurement Functions
- Transformer Functions
- Switch Functions
- Reactive Functions
- Protection Functions
- Distance (DIST)
- Synchronizing or Synchronism-Check (SYNC)
- High Impedance Ground Detector (HIZR)
- Directional Overcurrent (DOCR)
- Reclosing Relay (RECR)
- Differential Relay (DIFF)
- Measurement Unit
- Basic RTU Object Models
- Transformer Object Models
- Switch Object Model
- Automated Switch Controller Object Model
- Circuit Breaker Controller Object Model
- Recloser Control Object Model
- Reactive Component Object Models

These object models provide the interoperability of the various devices and systems connected in substations. They define the semantic of operations.

6 UCA substation demonstration initiative

EPRI’s UCA Substation Communications Automation project has as its goal to produce industry consensus regarding Substation Integrated Control, Protection and Data Acquisition, and to allow interoperability of substation devices from different manufacturers. To this end, an open process has been followed on this project, to review each major project document and milestone in the open forum of standards-related organizations. The initiative is an excellent opportunity to present the benefits of the (redundant) Fast Ethernet and the device modeling technology.

The UCA 2.0 profiles for field equipment communications are separated into Application Profiles, Transport Profiles, and Data Link Profiles. These profiles are combined to form complete Profiles that can meet different requirements.

By adopting existing standards, the utility can take advantage of the economies of scale of the electric utility and industrial control industry that has made extensive use of these protocols. The substation initiative is now supported by some 30 utilities and 25 Substation device and systems vendors:

Utilities:
- American Electric Power
- Arizona Electric Power Cooperative
- Ameren
- Boston Edison
- Baltimore Gas & Electric
- Bonneville Power Administration
- Cinergy
- CFE - Mexico
- ComEd
- ConEd
- Duke
- Duquesne Light and Power
- ESKOM
- Florida Power Corp
- GPU Energy
- Indianapolis Power & Light
- National Grid Co
- Northern States Power
- NUON
- Ontario Hydro
- Potomac Edison Power Co
- Pennsylvania Power and Light
- Southern California Edison
- Tampa Electric
- Texas Utilities
- Tennessee Valley Authority ...

Vendors:
- ABB
- Basler
- Beckwith
- Bitronics
- Cooper Power Systems
- Doble Instruments
- Dranetz/BMI
- Electrotech
- Alstom
- GE/Multilin Protection Sytems
- GE/Harris Energy Systems
- Telegyr
- Schneider Electric
- Sweitzer Engineering Labs
- Siemens
- Tasnet
- RFL
- Omicron
- Avo International
- Bailey Control Networks
- QEI Inc
- Toshiba
- Mitsubishi ...

7 Application in the gas industry

UCA was adapted by GRI (Gas research institute, USA) for use by gas utilities. This effort culminated in an evaluation of UCA in a gas utility environment at Pacific Gas and Electric Company, San Francisco. With gas industry operations becoming more complex, as the study shows, the benefits of UCA are significant. With UCA in place, system operators can more easily automate systems, gather operating data, exchange information, and analyze historical statistics. However, despite the potential savings, manufacturers report little demand from gas utilities for UCA-compliant equipment.

The benefits of UCA include:

- The enhanced ability to develop integrated business applications across functional areas.
- Simplified implementation of fully integrated communications networks.
- Purchasing alternatives from multiple vendors for compatible hardware and software.
- Reduced operating costs through reductions in installation, maintenance, operation, and training.
- An enhanced ability to respond quickly to the continuing changes of a less regulated, more competitive business environment while still offering value-added customer services.

At Pacific Gas and Electric Company, UCA-compliant equipment was used to collect distribution system data (e.g., pipeline pressures, flow rates, and gas quality) at regulator stations and throughout a distribution piping system, along with information on customer load, weather, cathodic protection, and other conditions. The estimated cost savings demonstrated in the field experiment, extrapolated to the gas industry as a whole, is $133 million, with the potential for an additional $47 million savings ($180 million total) by further integrating and consolidating data collection and monitoring functions into a single "intelligent electronic device" at field sites.

8 Summary

Deregulation will place greater demands for information on utilities than they have experienced before. IEEE’s UCA TR 1550 provides a timely, cost-effective, and standardized solution to allow advanced IED functions and distributed systems to form the foundation for 'next Generation' electric utility protection, control, and monitoring systems.

The benefactors of the results of open device data integration span the entire industry and include all of the stake-holders in this industry. The customers are in a position to save large sums of money and time. The vendors who provide solutions that meet or exceed expectations will become very successful. This is an exciting time in the industry with an inexorable move toward practical software components.

The most important issues are the models of the real device data and the rules (service interface) how to access these data. On the other side it is obvious that an appropriate transport mechanism (communication profiles), e.g., the TCP/IP or a point-to-point link, must be used to exchange the messages between devices.

By providing a common communications protocol stack, UCA allows a utility and other industries to “plug and play” equipment from different vendors. The specification of the uniquely tagged semantic of the most important device model data leads to a tremendous cost reduction during engineering, commissioning, operation, and maintenance.

References

1. IEEE Technical Report 1550 (1999): Utility Communications Architecture, UCA
2. IEC 60870-6-TASE.2: Telecontrol application service element 2
3. Committee drafts IEC 61850-7-y: Communication networks and systems in substations – Basic communication systems