Communication Protocols
1. 7 Layer Model
2. Communication Relationships
3. Topologies
4. Substation Implementation (UCA)
5. Traditional Protocols (Modbus, IEC 870-5 T103)
6. Net DDE vs. OPC
7. Inter Control Center Protocol (ICCP)
Communication Protocols and Standards
Protocol

A set of rules for operating a communication system

Areas addressed by rules:

- Framing
- Error Control
- Sequence Control
- Transparency

- Line Control
- Timeout Control
- Startup Control
- Special Cases
Communications Model

• ISO 7 Layer Model

• Enhanced Performance Architecture

• Basic Network Topologies
The Open Systems Interconnection
Seven Layer Reference Model

User A

Layer 7: Application
Layer 6: Presentation
Layer 5: Session
Layer 4: Transport
Layer 3: Network
Layer 2: Data Link
Layer 1: Physical

User to User Communications
User to User Encoded Communications
User to User
User to User Messages
User to User Packets
End to End Packets
End to End Bits
Communication Signals

User B

Application
Presentation
Session
Transport
Network
Data Link
Physical
# 3-LAYER LAN ARCHITECTURE

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>DNP 3.0 / Modbus / 870-5</td>
</tr>
<tr>
<td>Data Link</td>
<td>870-5 FT3</td>
</tr>
<tr>
<td></td>
<td>Modbus</td>
</tr>
<tr>
<td></td>
<td>870-5 FT1.2</td>
</tr>
<tr>
<td>Physical</td>
<td>RS-232</td>
</tr>
<tr>
<td></td>
<td>RS-485</td>
</tr>
<tr>
<td></td>
<td>Radio</td>
</tr>
</tbody>
</table>
Basic Communication Relationships

Peer to Peer
• Client / Server
• Publisher / Subscriber

Master / Slave
• Request / Response
• Response Only
TOKEN-RING CONCEPTS
The Next Generation

Communication to Central Computer

- Substation Computer
- Other Substation Functions
- Remote Communication Controller

Protection Module #1
Protection Module #2
Protection Module #3

Data Acquisition Unit #1
Data Acquisition Unit #2
Data Acquisition Unit #3

Connection Via Passive Optical Splitter

Line #1
Line #2
Line #N

High Speed Peer-to-Peer Communication
"STAR" Architecture

IED

Hub
Active/ Passive

IED

IED

IED

IED
Interoperability

Applications and devices can exchange useful information across business functions without the user having to engineer it.
Utility Communication Architecture - UCA
Utility Communication Architecture - UCA

- Arose from the need for common communication across the utility enterprise
- Basic definition started in 1988
- Defines a “suite” of protocols to address all utility communication requirements
- Has recently focused on Substation Communications
## 7-LAYER UCA MODEL

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocols/Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>MMS (1988)</td>
</tr>
<tr>
<td>Presentation</td>
<td>MHS (1984)</td>
</tr>
<tr>
<td>Session</td>
<td>ISO Connection-orientated Session</td>
</tr>
<tr>
<td>Transport</td>
<td>ISO/TCP Connection-orientated Transport</td>
</tr>
<tr>
<td>Network</td>
<td>ISO/IP Connectionless Network</td>
</tr>
<tr>
<td>Network Interface</td>
<td>ES-IS Routing, X.25 Packet Layer, ISDN Q.931</td>
</tr>
<tr>
<td>Data Link</td>
<td>LLC, FDDI, CSMA/CD (8802/3), Token Bus (8802/4), Token Ring (8802/5), ISDN LAPD</td>
</tr>
<tr>
<td>Physical</td>
<td>HDLC/LAPB, V.35, EIA-232-D, X.21, ISDN Interaces</td>
</tr>
</tbody>
</table>

### Protocol Overview
- **MMS (1988)**: ISO standard for manufacturing automation systems
- **MHS (1984)**: ISO standard for high-level data interchange
- **ACSE**: Application Services Envelope
- **ROSE**: Resource Oriented Service Environment
- **RTSE**: Remote Terminal Service Environment
- **ISO Connection-orientated Presentation**
- **ISO Connection-orientated Session**
- **ISO/TCP Connection-orientated Transport**: 0 and 4
- **LLC**: Logical Link Control
- **FDDI**: Fiber Distributed Data Interface
- **CSMA/CD (8802/3)**, **Token Bus (8802/4)**, **Token Ring (8802/5)**, **ISDN LAPD**
Substation Integrated
Protection, Control and Data Acquisition
Phase 1, Task 2
Requirements Specification

Project/Documentation Site:
Ftp.sisconet.com/epri/subdemo
Utilities Participating in UCA

- American Electric Power (AEP)
- Indianapolis Power & Light
- Ontario Hydro - Canada
- Northern States Power
- Tampa Electric
- ComEd
- Cinergy
- Baltimore Gas & Electric
- GPU
- Nuon - Holland

- Enetergy
- TVA
- Duke
- Boston Edison
- Union Electric
- Florida Power Corp
- Southern California Edison
- Wisconsin Electric
- ESKOM - South Africa
- National Grid Company - UK
- Polish Power Grid - Poland
Participating UCA Vendors

- GE Power Management
- Basler
- Cooper
- Beckwith
- Tasnet
- SEL
- GE Harris
- RFL

- Siemens
- Alstom
- L&G
- Doble
- Dranetz / BMI / Electrotek
- Modicon / Square D
- ABB
- Bitronics
IEC STATUS

- IEC TC 57 - Working Groups 10, 11, 12 are developing an IED peer to peer communication standard
- The work exists as the IEC - 61850 committee draft
- Section 8.1 is based on the MMS/Ethernet UCA Substation profile
- UCA and IEC 61850 will be reconciled
ETHERNET Description
Carrier Sense Multiple Access / Collision Detection
CSMA / CD

CSMA Concept: Listen for traffic on the network. If none, proceed to transmit data.

A *collision* occurs when two terminals transmit at the same time.
Initial test configuration for 10 Mbps Ethernet using Intel Pentium III based computers

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>10BaseT (Twisted Pair)</td>
<td>Fail</td>
</tr>
<tr>
<td>10Base2 (Coax)</td>
<td>Fail</td>
</tr>
<tr>
<td>10BaseF (Fiber)</td>
<td>Pass</td>
</tr>
</tbody>
</table>
MMS Service Specification

• Defines a set of objects that can exist within a device.

• Defines a set of communication services to access and manipulate those objects.

• Defines the behavior of the device to those communication services.
MMS Objects

- Domain
- Program Invocation
- Variable
- Type (Variable)
- Semaphore (2)
- Operator Interface

- Event Condition
- Event Action
- Event Enrollment
- Journal
- File
Named Variable Object

• A named MMS object representing a “real” variable
• Only the name is needed to access

• Attributes:
  - Object Name (scope)
  - MMS Deletable (boolean)
  - Type description
  - Access method (Public, etc.)
  - Address (Public only)

• Be careful about using addresses in where the address can change from on run-time to the next.
Simple Type Definition

- A Simple Type definition consists of Class and Size

- Type Classes:
  
  BOOLEAN          VISIBLE STRING
  BIT STRING       OCTET STRING
  INTEGER          GENERAL TIME (ISO)
  UNSIGNED (INT)   BINARY TIME (MMS/C)
  FLOAT (IEEE)     BCD
  REAL (ISO)

- Although MMS Data has the form information built-in (integer, string, boolean, etc.), only the Type Def'n has the size information needed to convert to local format.
Domain

- Represents a resource within the VMD.
- Domains are typically:
  - Program Memory
  - Recipe Memory
  - Data Memory, etc.
- Domains may be pre-named.
MMS Services

- Get Object
- Change Object
- Determine Attributes
- Create Object
- Delete Object
Domain Services

- Upload: 
  - InitiateUploadSequence
  - UploadSegment
  - TerminateUploadSequence

- Download: 
  - InitiateDownloadSequence
  - DownloadSegment
  - TerminateDownloadSequence

Each upload sequence is assigned a unique ID Number to track multiple uploads in progress.

Domain data is sent over the network in segments

InitiateDownloadSeq creates domain
  - If domain exists: must delete first
Unconfirmed Services

• Unconfirmed services consist of only the request and indication service primitives.
  
  • UnsolicitedStatus
  
  • InformationReport
  
  • EventNotification
Program Invocations

• An execution thread consisting of one or more domains.

• A program invocation can be started, stopped, etc.

• A P.I. May be pre-named
Common Application Service Models (CASM)

- Generic communications services
  - data access
  - data (and exception) reporting
  - device control, tagging
  - self describing devices

- Detailed mapping of data objects to MMS

- Detailed mapping of generic services to MMS services
Common Application Service Model

MMS Services Required

<table>
<thead>
<tr>
<th>MMS PDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment and General Management</td>
</tr>
<tr>
<td>Initiate</td>
</tr>
<tr>
<td>Conclude</td>
</tr>
<tr>
<td>Abort</td>
</tr>
<tr>
<td>VMD Management</td>
</tr>
<tr>
<td>GetNameList</td>
</tr>
<tr>
<td>PutNameList</td>
</tr>
<tr>
<td>GetCapabilityList</td>
</tr>
<tr>
<td>Domain Management</td>
</tr>
<tr>
<td>InitiateDownloadSequence</td>
</tr>
<tr>
<td>DeleteDomain</td>
</tr>
<tr>
<td>Variable Access</td>
</tr>
<tr>
<td>Read</td>
</tr>
<tr>
<td>Write</td>
</tr>
<tr>
<td>InformationReport</td>
</tr>
<tr>
<td>GetVariableAccessAttributes</td>
</tr>
<tr>
<td>DefineNamedVariable</td>
</tr>
<tr>
<td>DeleteNamedVariable</td>
</tr>
<tr>
<td>GetNamedVariableListAttributes</td>
</tr>
<tr>
<td>DefineNamedVariableList</td>
</tr>
<tr>
<td>DeleteNamedVariableList</td>
</tr>
<tr>
<td>DeleteNamedVariableList</td>
</tr>
<tr>
<td>ServiceError</td>
</tr>
</tbody>
</table>
General Object Model for Substation & Field Equipment (GOMSFE)

- Object Modeling is a technique for identifying data elements in a device.
- Defines standards names, attributes, and behaviors of the data elements
- Allows the re-use of names
- Provides the foundation for the information needed for “self-description”
# Measurement Unit

<table>
<thead>
<tr>
<th>Object Name</th>
<th>Class</th>
<th>wnc</th>
<th>m/o</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Current in phases and neutral</td>
</tr>
<tr>
<td>ResA</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Residual Current</td>
</tr>
<tr>
<td>DmdResA</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Present Demand Residual Current</td>
</tr>
<tr>
<td>MaxDmdResA</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Max Demand Residual Current</td>
</tr>
<tr>
<td>DmdA</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Present Demand Amps (interval is DmdInt)</td>
</tr>
<tr>
<td>MaxDmdA</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Max Demand Amps (interval is DmdInt)</td>
</tr>
<tr>
<td>HaA</td>
<td>HI</td>
<td>r</td>
<td>0</td>
<td>Individual Harmonic Currents</td>
</tr>
<tr>
<td>KfA</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>K Factor in phases only</td>
</tr>
<tr>
<td>Voltage Information:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Voltage phase to ground</td>
</tr>
<tr>
<td>PhsPhsV</td>
<td>DELTA</td>
<td>0</td>
<td>0</td>
<td>Voltages phase to phase</td>
</tr>
<tr>
<td>ResV</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Residual voltage</td>
</tr>
<tr>
<td>HaV</td>
<td>HI</td>
<td>r</td>
<td>0</td>
<td>Individual Harmonic Voltages</td>
</tr>
<tr>
<td>DmdPhsV</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Present Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>MinDmdPhsV</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Min Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>MaxDmdPhsV</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Max Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>DmdPhsPhsV</td>
<td>DELTA</td>
<td>0</td>
<td>0</td>
<td>Present Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>MinDmdPPV</td>
<td>DELTA</td>
<td>0</td>
<td>0</td>
<td>Min Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>MaxDmdPPV</td>
<td>DELTA</td>
<td>0</td>
<td>0</td>
<td>Max Demand volts (interval is DmdInt)</td>
</tr>
<tr>
<td>Sequence Components</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SeqA</td>
<td>Seq</td>
<td>r</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SeqV</td>
<td>Seq</td>
<td>r</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Energy Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>Watts per phase</td>
</tr>
<tr>
<td>TotW</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total Watts in all 3 phases.</td>
</tr>
<tr>
<td>TotWthr</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total Watt Hours</td>
</tr>
<tr>
<td>Var</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>VAr per phase</td>
</tr>
<tr>
<td>TotVAR</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total VArS in all 3 phases.</td>
</tr>
<tr>
<td>TolVAthr</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total VArh</td>
</tr>
<tr>
<td>VA</td>
<td>WYE</td>
<td>0</td>
<td>0</td>
<td>VA per phase</td>
</tr>
<tr>
<td>TotVA</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total VA in all 3 phases.</td>
</tr>
<tr>
<td>DmdTVA</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Demand</td>
</tr>
<tr>
<td>DmdInt</td>
<td>INT16U</td>
<td>0</td>
<td>0</td>
<td>Demand Interval in sections</td>
</tr>
<tr>
<td>TotPosWhr</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total Watt Hours positive (in normal direction)</td>
</tr>
<tr>
<td>TolNegWhr</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total Watt Hours negative (in reverse direction)</td>
</tr>
<tr>
<td>TolVgWhr</td>
<td>AI</td>
<td>0</td>
<td>0</td>
<td>Total VAr Hours positive (lagging)</td>
</tr>
<tr>
<td>FC</td>
<td>Object Name</td>
<td>Class</td>
<td>rwec</td>
<td>m/o</td>
</tr>
<tr>
<td>-----</td>
<td>----------------</td>
<td>-------</td>
<td>------</td>
<td>--------------------</td>
</tr>
<tr>
<td></td>
<td>TotLeVAHr</td>
<td>AI</td>
<td>o</td>
<td>Total VA Hours negative (leading)</td>
</tr>
<tr>
<td></td>
<td>DmdTotW</td>
<td>AI</td>
<td>o</td>
<td>Present Demand Total Watts (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MinDmdTotW</td>
<td>AI</td>
<td>o</td>
<td>Min Demand Total Watts (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MaxDmdTotW</td>
<td>AI</td>
<td>o</td>
<td>Max Demand Total Watts (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>DmdTotVar</td>
<td>AI</td>
<td>o</td>
<td>Present Demand Total Var (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MinDmdTotVar</td>
<td>AI</td>
<td>o</td>
<td>Min Demand Total Var (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MaxDmdTotVar</td>
<td>AI</td>
<td>o</td>
<td>Max Demand Total Var (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MinDmdTotVA</td>
<td>AI</td>
<td>o</td>
<td>Min Demand Total VA (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>MaxDmdTotVA</td>
<td>AI</td>
<td>o</td>
<td>Max Demand Total VA (interval is DmdInt)</td>
</tr>
<tr>
<td></td>
<td>Power Factor Information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>Power Factor for each phase</td>
</tr>
<tr>
<td>TotPF</td>
<td>AI</td>
<td></td>
<td>o</td>
<td>Total Power Factor of all 3 phases.</td>
</tr>
<tr>
<td>DispPF</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>Displacement PF (using fundamental only)</td>
</tr>
<tr>
<td>TotDispPF</td>
<td>AI</td>
<td></td>
<td>o</td>
<td>Total Displacement PF (using fundamental only)</td>
</tr>
<tr>
<td>Frequency Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hz</td>
<td>AI</td>
<td></td>
<td>o</td>
<td>Frequency</td>
</tr>
<tr>
<td>Miscellaneous Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDDA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>Total Demand Distortion Amps by phase</td>
</tr>
<tr>
<td>TDDOddA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>TDD Amp odd components</td>
</tr>
<tr>
<td>TDDEvenA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>TDD Amp even components</td>
</tr>
<tr>
<td>THDA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>Total Harmonic Distortion Amps by phase</td>
</tr>
<tr>
<td>THDDoddA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>THD Amp odd components</td>
</tr>
<tr>
<td>THDEvenA</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>THD Amp even components</td>
</tr>
<tr>
<td>THDPhsV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>THD Volts phase-to-ground</td>
</tr>
<tr>
<td>THDDoddPhsV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>THD Volts odd components</td>
</tr>
<tr>
<td>THDEvenPhsV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>THD Volts even components</td>
</tr>
<tr>
<td>THDPPhV</td>
<td>DELTA</td>
<td></td>
<td>o</td>
<td>THD Volts phase-to-phase</td>
</tr>
<tr>
<td>THDDoddPPhV</td>
<td>DELTA</td>
<td></td>
<td>o</td>
<td>THD Volts odd components</td>
</tr>
<tr>
<td>THDEvenPPhV</td>
<td>DELTA</td>
<td></td>
<td>o</td>
<td>THD Volts even components</td>
</tr>
<tr>
<td>TDDPPhV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>TDD Volts phase-to-ground</td>
</tr>
<tr>
<td>TDDOddPPhV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>TDD Volts odd components</td>
</tr>
<tr>
<td>TDDEvenPPhV</td>
<td>WYE</td>
<td></td>
<td>o</td>
<td>TDD Volts even components</td>
</tr>
<tr>
<td>SP</td>
<td>AO</td>
<td></td>
<td>rw</td>
<td>Current used in TDD amp calculation</td>
</tr>
<tr>
<td>ShCktRat</td>
<td>AO</td>
<td></td>
<td>rw</td>
<td>Short Circuit Ratio</td>
</tr>
<tr>
<td>CO</td>
<td>BO</td>
<td></td>
<td>w</td>
<td>Reset all min and max values</td>
</tr>
<tr>
<td>CF</td>
<td>ACF</td>
<td></td>
<td>rw</td>
<td>Configuration for all included MX</td>
</tr>
<tr>
<td>MX</td>
<td>BTIME6</td>
<td></td>
<td>m</td>
<td>Date and time for data logging.</td>
</tr>
<tr>
<td>Cimg</td>
<td>AcctBLOB</td>
<td></td>
<td>rw</td>
<td>Proprietary Information</td>
</tr>
<tr>
<td>DC</td>
<td>EqRtg</td>
<td></td>
<td>m</td>
<td>Equipment rating</td>
</tr>
<tr>
<td>EqRtg</td>
<td>ConCkt</td>
<td></td>
<td>m</td>
<td>Connected Circuit</td>
</tr>
<tr>
<td>DC</td>
<td>ConCkt</td>
<td></td>
<td>m</td>
<td>Description of all included MX</td>
</tr>
<tr>
<td>RP</td>
<td>BasRCB</td>
<td></td>
<td>m</td>
<td>Controls reporting of Analog Inputs</td>
</tr>
</tbody>
</table>
Data Modeling Concept

Relay Data

Externally Visible Objects

- Measurement Unit
  - READ
  - CONFIGURE
- Settings
  - READ
  - WRITE
- SBO
- Position
  - OPEN
  - CLOSE
- Files
  - GET

Vendor Internal Memory

- Voltages
- Currents
- Watts
- Vars
- Settings
- Controls
- SOE
- Oscillography

GOMSFE + Vendor specific objects
“GOOSE” Format
(Generic Object Oriented Substation Event)

<table>
<thead>
<tr>
<th>Header</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DST=Source=local MAC address</td>
</tr>
<tr>
<td>• Multicast</td>
</tr>
<tr>
<td>• Relay Name</td>
</tr>
<tr>
<td>• Time of event</td>
</tr>
<tr>
<td>• Time until next GOOSE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Dynamic Network Announcement)</td>
</tr>
<tr>
<td>• 32 Standard Bit Pairs, e.g. Close, Open, BFI, RI, etc.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>User Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 64 “user defined” bit pairs</td>
</tr>
</tbody>
</table>

- Message sent as an “unconfirmed” MMS information report
- Use the Ethernet Multicast Format, i.e. the MSB of the message is set to a “1”
- Data is sent in bit pairs where:
  - 01 = 0
  - 10 = 1
  - 00 = “Transition”
  - 11 = Undefined
Relationship of CASM and GOMSFE
Substation Automation
Original RTU Concept

- Single box
- All signals hard wired to the single box
- Limited data availability
- Analog
- Status
- Alarm
- Complete overlay of Protection

To SCADA Master

RTU
Substation Automation
Relay Based SCADA

- Substation Host becomes Data Concentrator
- Data acquisition is performed by all IEDs in the substation
- Distributed SOE available through IRIG-B time sync
- Oscillography data now available
FSC
(Fiber Optic System Communications)

- SONET Technology: 51/155 Mbps
- Ethernet LAN ‘Bridging’ capability
- Creates single Ethernet WAN
- Redundant channels ensure reliability
**Architectural Concept**

- **Open Architecture**
- **Commercial Hardware and Software**
- **Easy to Expand and Integrate**
- **Cost Effective Standard Packages**

**Enterprise**

- **GUI/SCADA/other applications**
- **Data Server and Database**
- **Data Collection Engine**
- **Physical Communication Drivers**
  - Modbus, GE Modem, DNP, MMS, other
  - IEDs

**File Storage**
- Oscillography
- SOE
- Demand Data

**Other Apps:**
- OSC Viewer
- SOE Viewer
DDE and OPC

Overview and Comparison
• DDE - Dynamic Data Exchange

• Method for exchanging data between applications

![Diagram showing DDE communication between HMI (DDE Client) and Driver (DDE Server)]
The DDE Data Model

DDE Application

DDE Topic(s)

DDE Item(s)
How DDE Works

DDE Client 1

DDE Client 2

DDE Client 3

DDEML.DLL
(DDE Management Library)

DDE Server 1

DDE Server 2

DDE Server 3
What is OPC

• OPC - OLE for Process Control
• A Specification for software interoperability in the automation industry.
• Based upon Microsoft Component Object Model (COM)
The OPC Data Model

OPCServer

OPCGroup(s)

OPCItem(s)

OPCItem(s)

OPCItem(s)

OPC Driver
How OPC Works

OPC Client 1

OPC Client 2

OPC Client 3

OPC Server 1

OPC Server 2

OPC Server 3
DDE
• Passes 1 value per request
• No time stamp
• No "quality" flag
• No underlying structure similar to OLE
• High resource utilization

OPC
• Can pass multiple values per request
• Time stamp standard part of the response
• "Quality" flag standard part of the response
• Based on OLE/COM
• Low resource utilization
Wizard Selection

GE Miscellaneous
GE One-Line Tools
GE Large Faceplates
GE Tabular Screens
GE Small Faceplates I
GE Small Faceplates II
GE Elevation Wizard I
GE Elevation Wizard II
GE Floorplan Wizard I
GE Floorplan Wizard II
Alarm Displays
Buttons
Clocks
Frames
Panels
Lights
Meters
Runtime Tools
Sliders

Wizard Description
GE DFP200 Large Faceplate Wizard

Short Comment
GE DFP200 Large Faceplate

Select  Cancel  Add to Toolbox  Remove from Toolbox...
## Annunciator Screen

<table>
<thead>
<tr>
<th>System</th>
<th>Diagrams</th>
<th>Alarms</th>
<th>Operations</th>
<th>Demo Tools</th>
<th>Help</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer #1 Misc. Trouble</td>
<td>Transformer #2 Misc. Trouble</td>
<td>Supervisory Control Cabinet DC Supply Lost</td>
<td>Loss of Annun DC Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transformer #1 Tap Chgr Hanguip &amp; LTC Trouble</td>
<td>Transformer #2 Tap Chgr Hanguip &amp; LTC Trouble</td>
<td>Switchgear #1 Misc. Trouble</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switchgear #1 Misc. Trouble</td>
<td>Switchgear #2 Misc. Trouble</td>
<td>Transformer #2 Tap Chgr Hanguip &amp; LTC Trouble</td>
<td>Loss of Annun DC Supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switchgear #1 Flex-Test SW Open</td>
<td>Switchgear #2 Flex-Test SW Open</td>
<td>Transformer #2 Tap Chgr Hanguip &amp; LTC Trouble</td>
<td>Switchgear #1 Misc. Trouble</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switchgear #1 Hi-Low Temperature</td>
<td>208V Load Shedding Trouble</td>
<td>Circuit Breaker Auto Trip</td>
<td>Local Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backup Relay Panel T1 Trouble</td>
<td>Backup Relay Panel T2 Trouble</td>
<td>Backup Relay Panel T1 Trouble</td>
<td>Transformer #2 Flex-Test SW Open</td>
<td>Backup Relay Panel T1 Trouble</td>
<td></td>
</tr>
<tr>
<td>120/208 MISC &amp; Panel Transfer SW</td>
<td></td>
<td>Backup Relay Panel T1 Trouble</td>
<td>Transformer #2 Tap Chgr Hanguip &amp; LTC Trouble</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Legend:
- Normal/Alarm Off
- Alarm Off, Unacknowledged
- Alarm On, Unacknowledged
- Alarm On, Acknowledged
- Alarm Disabled

**Buttons:**
- Reset
- Acknowledge All
- Alarm Summary
- Help

**User:** go  
**Date:** 4/23/98  
**Time:** 9:33:30 AM

---

55

---

01. Communication Protocols
### Sequence of Events

<table>
<thead>
<tr>
<th>TimeStamp</th>
<th>EventType</th>
<th>SourceName</th>
<th>SourceType</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/11/1997 03:21:45.123</td>
<td>Fault</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>TransA1</td>
</tr>
<tr>
<td>03/15/1997 19:16:45.036</td>
<td>Logout</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>MaintMan1</td>
</tr>
<tr>
<td>03/28/1997 11:10:45.496</td>
<td>Fault</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>Fccdcr1</td>
</tr>
<tr>
<td>04/01/1997 09:12:45.111</td>
<td>Waveform</td>
<td>SR745_T1</td>
<td>ML745</td>
<td>Breaker2 - Br2.CSV</td>
</tr>
<tr>
<td>04/01/1997 10:19:55.222</td>
<td>Event</td>
<td>DFP_23A</td>
<td>DFP100</td>
<td>Breaker2 Tripped</td>
</tr>
<tr>
<td>04/01/1997 11:12:45.010</td>
<td>Waveform</td>
<td>DFP_23A</td>
<td>DFP100</td>
<td>Breaker1 - Br1.CSV</td>
</tr>
<tr>
<td>04/01/1997 12:19:55.432</td>
<td>Event</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>Breaker1 Tripped</td>
</tr>
<tr>
<td>04/01/1997 13:03:35.123</td>
<td>Man Trip</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>Breaker1</td>
</tr>
<tr>
<td>04/01/1997 10:06:15.110</td>
<td>Login</td>
<td>DFP_11B</td>
<td>DFP100</td>
<td>MaintMan1</td>
</tr>
</tbody>
</table>
GPS/IRIG-B Time Synchronization

To Legacy SCADA System

Dial-up Remote Access

Modem

Port Server

Serial Comms.

IEDs

IEDs

IEDs

Distribution Amplifier

IRIG-B signal

Fiber Optic

GPS Clock

IRIG-B signal
### TABLE G2. 4 Bit Quality Indicator Code

<table>
<thead>
<tr>
<th>BINARY</th>
<th>HEX</th>
<th>VALUE (worst case accuracy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111</td>
<td>F</td>
<td>Fault--Clock failure, time not reliable</td>
</tr>
<tr>
<td>1011</td>
<td>B</td>
<td>10 seconds</td>
</tr>
<tr>
<td>1010</td>
<td>A</td>
<td>1 second</td>
</tr>
<tr>
<td>1001</td>
<td>9</td>
<td>100 milliseconds (time within 0.1 sec)</td>
</tr>
<tr>
<td>1000</td>
<td>8</td>
<td>10 milliseconds (time within 0.01 sec)</td>
</tr>
<tr>
<td>0111</td>
<td>7</td>
<td>1 millisecond (time within 0.001 sec)</td>
</tr>
<tr>
<td>0110</td>
<td>6</td>
<td>100 microseconds (time within $10^{-4}$ sec)</td>
</tr>
<tr>
<td>0101</td>
<td>5</td>
<td>10 microseconds (time within $10^{-5}$ sec)</td>
</tr>
<tr>
<td>0100</td>
<td>4</td>
<td>1 microsecond (time within 10-6 sec)</td>
</tr>
<tr>
<td>0011</td>
<td>3</td>
<td>100 nanoseconds (time within 10-7 sec)</td>
</tr>
<tr>
<td>0010</td>
<td>2</td>
<td>10 nanoseconds (time within 10-8 sec)</td>
</tr>
<tr>
<td>0001</td>
<td>1</td>
<td>1 nanosecond (time within 10-9 sec)</td>
</tr>
<tr>
<td>0000</td>
<td>0</td>
<td>Normal operation, clock locked</td>
</tr>
</tbody>
</table>
IRIG FORMAT ‘B’ - GENERAL

1. **TIME FRAME:** 1.0 second.

2. **CODE DIGIT WEIGHTING OPTIONS:** BCD, SB or both:
   a) Binary Coded Decimal Time-of-Year CODE WORD - 30 binary digits.
      (1) Seconds, minutes, hours and days. Recycles yearly.
   b) Straight Binary Time-of-Day CODE WORD - 17 binary digits.
      (1) Seconds only. Recycles each 24 hours. (86399)

3. **CODE WORD STRUCTURE:**
   a) **BCD:** Word begins at INDEX COUNT 1. Binary-coded elements occur between POSITION IDENTIFIER ELEMENTS (seven for seconds, seven for minutes: six for hours: ten for days) until the CODE WORD is complete. A POSITION IDENTIFIER occurs between decimal digits in each group to provide separation for visual resolution.
   b) **SB:** Word begins at INDEX COUNT 80. Seventeen binary-coded elements occur with a POSITION IDENTIFIER between the 9th and 10th binary-coded elements.
IRIG FORMAT ‘B’ - GENERAL

4. Least significant digit: occurs first.

5. ELEMENT RATES AVAILABLE:
   a) 100 per second (basic Element rate)
   b) 10 per second (POSITIVE IDENTIFIER Rate)
   c) 1 per second (Frame Rate)

6. ELEMENT IDENTIFICATION:
   a) ‘On-Time’ reference point for each Element is its leading edge.
   b) INDEX MARKER duration: 2 milliseconds
      (Binary zero or uncoded Element)
   c) CODE DIGIT duration: 5 milliseconds
      (Binary one)
   d) POSITION IDENTIFIER duration: 8 milliseconds
   e) REFERENCE MARKER - one per second: Two consecutive
      POSITION IDENTIFIERS.
      (The ‘On-Time’ point to which the CODE WORD refers, is the
      leading edge of the second POSITION IDENTIFIER.)
IRIG FORMAT ‘B’ - GENERAL

7. **RESOLUTION**: 10 milliseconds (unmodulated); 1 millisecond (modulated).

8. **CARRIER FREQUENCY**: 1 kHz when modulated.
Modified IRIG-B Code as specified by the IEEE Synchrophasor Standard:

DISCUSSION OF BIT ASSIGNMENTS:
By using IRIG-B with additional extensions, old and new time sources and time users can be easily integrated. PMU’s should be programmed to check the control bit field and use this additional information where it is provided but rely on user entered data where it is not. Since unused control field bits are normally set to zero, where possible these new assignments are made with zero indicating a normal state. This will minimize the possibility of creating a false alarm. For example, if a control field was all zeroes, the time quality code would indicate the clock was locked with full accuracy which would not accidentally be interpreted as an error condition.
DISCUSSION CONT’D:

Virtually every timekeeping system is run by some kind of processor. Since IRIG time code numbers arrive AFTER the on time mark, the timekeeping system must generate the timetag based on the anticipated number rather than on what it just got. Consequently time counts that are not in exact sequence require advance notice. Non-sequence clock counts include leap year, leap second, and daylight savings time changes. The Leap second and Daylight savings change bits warn of impending special clock counts, and the last two digits of the year alert the timing system of leap year changes.
Traditional Protocols

• ModBus
• DNP
• IEC 870-5
• T103
ModBus
ModBus Basic Features

- Master-Slave Protocol
- Can Address up to 254 slaves
- All data is accessed via register addresses
- Primarily defined on RS485 - also has been operated on Ethernet
- Data is addressed via 2-byte registers
- ModBus Packet can transmit up to 120 registers per message
- Registers accessed must be sequential
### ModBus Packet Format

<table>
<thead>
<tr>
<th>Slave Address</th>
<th>Function Code</th>
<th>Data up to 120 regs.</th>
<th>CRC16 2 bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte</td>
<td>1 byte</td>
<td>=240 Bytes</td>
<td></td>
</tr>
</tbody>
</table>

* Packet must be followed by 3.5 byte times of “dead time”

**Note:**
- Each register is 2 bytes
- Most Significant Data bytes are sent first
- Least Significant CRC byte is sent first
<table>
<thead>
<tr>
<th>HEX Function Code</th>
<th>MODBUS Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Read Holding Register</td>
</tr>
<tr>
<td>4</td>
<td>Read Holding Register</td>
</tr>
<tr>
<td>5</td>
<td>Force Single Coil</td>
</tr>
<tr>
<td>6</td>
<td>Preset Single Register</td>
</tr>
<tr>
<td>10</td>
<td>Preset Multiple Registers</td>
</tr>
</tbody>
</table>
The following table shows the format of the master and slave packets. The example shows a master service requesting 3 register values starting at address 200h from slave device 11; the slave device responds with the values 555, 0, and 100 from registers 200h, 201h, and 202h respectively.

<table>
<thead>
<tr>
<th>Master Transmission</th>
<th>Slave Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet Format</td>
<td>Example (hex)</td>
</tr>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>03</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - hi</td>
<td>02</td>
</tr>
<tr>
<td>DATA STARTING ADDRESS - lo</td>
<td>00</td>
</tr>
<tr>
<td>NUMBER OF REGISTERS - hi</td>
<td>00</td>
</tr>
<tr>
<td>NUMBER OF REGISTERS - lo</td>
<td>03</td>
</tr>
<tr>
<td>CRC - lo</td>
<td>06</td>
</tr>
<tr>
<td>CRC - hi</td>
<td>E3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packet Format</th>
<th>Example (hex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAVE ADDRESS</td>
<td>11</td>
</tr>
<tr>
<td>FUNCTION CODE</td>
<td>03</td>
</tr>
<tr>
<td>BYTE COUNT</td>
<td>06</td>
</tr>
<tr>
<td>DATA #1 - hi</td>
<td>02</td>
</tr>
<tr>
<td>DATA #1 - lo</td>
<td>2B</td>
</tr>
<tr>
<td>DATA #2 - hi</td>
<td>00</td>
</tr>
<tr>
<td>DATA #2 - lo</td>
<td>00</td>
</tr>
<tr>
<td>DATA #3 - hi</td>
<td>00</td>
</tr>
<tr>
<td>DATA #3 - lo</td>
<td>64</td>
</tr>
<tr>
<td>CRC - lo</td>
<td>C8</td>
</tr>
<tr>
<td>CRC - hi</td>
<td>BA</td>
</tr>
</tbody>
</table>
DNP

Distributed Network Protocol
What is DNP?

- Open Systems Protocol Stack
- Recommended by IEEE for RTU to IED messages
- Based on IEC 3-layer version of 7-layer OSI model
- Developed by Harris Controls and Released in 1993
- Controlled by DNP User’s Group since Nov. 1993

APPLICATION
DATA LINK
PHYSICAL
<table>
<thead>
<tr>
<th>ISO/OSI Layer</th>
<th>ISO/OSI Layer Definition</th>
<th>DNP 3.0 Implementation Reference</th>
<th>T101 Implementation Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical Layer</td>
<td>Variety of Asynchronous Serial Formats (V.24 if Modem used)</td>
<td>Unbalanced V.24/V.28, Balanced X.24/X.27</td>
</tr>
<tr>
<td>2</td>
<td>Data Link Layer</td>
<td>IEC 870-5 FT3, Asynchronous with Enhance Addressing</td>
<td>IEC 870-5 FT1.2</td>
</tr>
<tr>
<td>4</td>
<td>Transport Layer</td>
<td>Pseudo-Transport Layer provides segmentation for large messages</td>
<td>Not applicable to T101</td>
</tr>
<tr>
<td>7</td>
<td>Application Layer</td>
<td>DNP V3.00 Level 2 Subset (DNP L2)</td>
<td>Selection of ASDUs from IEC 870-5-4</td>
</tr>
</tbody>
</table>
• Based on IEC 870-5 standards
• Intended for evolution to a 7-layer stack
• Implemented by several vendors
• Multiple operating modes
  • Polled Only
  • Polled by Exception
  • Unsolicited Report by Exception
• Layered protocol allows mix-and-match
• Allows Multiple Masters
• Address capability over 65,000 devices and
• 4,000,000,000 data points of each data type
• Broadcast Messages
• Configuration / File Transfer
• Time of Day and Date Synchronization
• Time-Stamped Event Data
• Data Priority Levels By Classes
• Intended for low-to-medium speed media

• 16-bit Data Link CRC’s every 16 octets

• Hamming Distance of 6

• Optional Data Link and Application confirmation
• **Topologies**
  
  • Direct or Point to Point using cable, radios, modems
  
  • Serial Bus or Local Area Network (LAN) using multi drop configuration

• **Modes**

  • Asynchronous, synchronous, isochronous
DNP Data Link Layer

- Accepts, performs, and controls transmission service for higher layers
- Provide for transfer of Link Service Data Units (LSDU) across the physical link
- Provide Frame Synchronization, Link Control, and Indications for Events
- Exchange of Service Data Units (SDU) between peer DNP data links
START 2 starting octets of the header (0x0564).
LENGTH 1 octet count of USER DATA in the header and body. This count includes the CONTROL, DESTINATION and SOURCE fields in the header. The CRC fields are not included in the count. The minimum value for LENGTH is 5 indicating only the header is present and the maximum value is 255.
CONTROL Frame control octet.
DESTINATION 2 octet destination address. The first octet is the LSB and the second octet is the MSB.
SOURCE 2 octet source address. The first octet is the LSB and the second octet is the MSB.
CRC 2 octet Cyclic Redundancy Check.
USER DATA Each block following the header has 16 octets of User defined data except the last block of a frame which contains 1 to 16 octets of User defined data as needed.
Requests and Responses

MASTER

Request

(Confirm)

Response

(Confirm)

Unsolicited Response

(Confirm)

SLAVE
• Pseudo transport layer acts as a DNP data link layer
• Assembles and Disassembles frames of 255 octets each
• Messages Control
  • Send Request
  • Accept Request
  • Confirmation
• Communications Error Recovery
  • Reported to User
  • User Layer Responsible for Corrective Procedure
• Messages Types
  • Requests
    • Confirm, Read, Write, Select, Operate, Freeze, Restart, Start and Stop Applications, Save Configuration, Enable and Disable Unsolicited Messages, Assign Class, Delay Measurement
  • Responses
    • Confirm, Response, Unsolicited Message
Data Object Examples

- Binary Inputs
- Binary Outputs
- Counters
- Analog Inputs
- Analog Outputs
- Time
- Classes of data
- Applications
- Numeric Formats

- Some Variations:
  - 16 or 32 bit
  - Static or Event
  - With or Without Flag
  - With or Without Time
  - Frozen or non-frozen
• A five part document detailing a “suite” of protocols for data communication
• Needs companion documents to detail a particular implementation
  • T103 (based on VDEW German Standard)
  • DNP (partially compliant)
• “Mostly” compatible with IEC 870-5
• Presently a Draft International Standard
• Specifies Physical Link options (RS485 & Fiber)
• Specifies the Data Link format (ft 1.2)
• Specifies the Application Layer data structures
• Defines standard “types” of data
• Allows for “Self Description”
• Operates in a Master / Slave mode
Application Service Data Unit

<table>
<thead>
<tr>
<th>DATA UNIT IDENTIFIER</th>
<th>TYPE IDENTIFICATION</th>
<th>DATA UNIT TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VARIABLE STRUCTURE QUALIFIER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAUSE OF TRANSMISSION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COMMON ADDRESS OF ASDU</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FUNCTION TYPE</td>
<td>INFORMATION OBJECT IDENTIFIER</td>
</tr>
<tr>
<td></td>
<td>INFORMATION NUMBER</td>
<td></td>
</tr>
<tr>
<td>APPLICATION SERVICE DATA UNIT</td>
<td>SET OF INFORMATION ELEMENTS</td>
<td></td>
</tr>
<tr>
<td>INFORMATION OBJECT</td>
<td>TIME TAG ms</td>
<td>TIME TAG OF INFORMATION OBJECT (optional)</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>Res.</td>
</tr>
<tr>
<td></td>
<td>SU</td>
<td></td>
</tr>
</tbody>
</table>
T103 Data Description Options

0  No description specified
1  Actual Value
2  Default Value
3  Range (min, max, step size)
4  Reserved
5  Precision
6  Factor
7  % Reference
8  Enumeration
9  Dimension
10 Description
12 Password Entry
13 Read Only
14 Write Only
Inter Control Center Protocol

(ICCp)
Also known as TASE.2 (Telecontrol Application Service Element.2)

Developed initially as a part of an Electric Power Research Institute (EPRI) Utility Communications Architecture (UCA) initiative

Submitted by USA to IEC TC 57 WG07

Only one set of IEC standards today
• Estimated 150-200 North American utility implementations completed or in development
• 10-20 Power Pools, Independent System Operators (ISOs)
• Multiple International projects in various stages of development
• NERC Inter-regional Security Network (ISN)
  – 18 ICCP Nodes serving 21 Security Coordinators
• UCPTE
• UCPTE (European NERC) using TASE.2 for European interconnection network over TCP/IP
  – Germany, Netherlands, Belgium, France, Spain, Portugal, Italy, former Yugoslavia, Austria, Switzerland, others
  – Impact on Eastern CENTREL interconnection network
    • Poland and others
  – Migration to ELCOM-90 planned
    • Netherlands, Belgium
• European deregulation - TASE.2
  – Security and energy schedules
ICCP Data Exchange Model

ICCP Data Objects

Site A

- SCADA/EMS Database
- Interchange Scheduling
- Power Plant Apps.
- Business Apps.

ICCP Provider

MMS Provider

Site B

- SCADA/EMS Database
- Interchange Scheduling
- Power Plant Apps.
- Business Apps.

ICCP Provider

MMS Provider

MMS PDU

- Indication Points
- Interchange Schedules
- Availability Report
- MMS Objects
ICCP Design Goals

• Vendor interoperability over any network

• Multiple transport profiles possible
  Lower layers transparent to ICCP
  Routable over various interconnected subnetworks

• Maximize use of existing ISO protocol standards in lower layers
  ICCP confined to sublayer in layer 7

• NOT
  Provide standard API
  Guarantee portability
### ICCP Protocol Architecture

<table>
<thead>
<tr>
<th>Layer</th>
<th>Protocol/Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>ICCP IEC 60870-6-503/802 MMS ACSE</td>
</tr>
<tr>
<td>Presentation</td>
<td>ISO Presentation</td>
</tr>
<tr>
<td>Session</td>
<td>ISO Session</td>
</tr>
<tr>
<td>Transport</td>
<td>ISO Transport Class 4 TCP</td>
</tr>
<tr>
<td>Network</td>
<td>ISO CLNP IP</td>
</tr>
<tr>
<td>Data Link</td>
<td>ISO 8802.2 LLC, FDDI, FR, ISDN, etc.</td>
</tr>
<tr>
<td>Physical</td>
<td>Ethernet LAN, WAN, Point-to-Point Circuit, ATM, SDH, etc.</td>
</tr>
</tbody>
</table>
CNP - Comm. Node Processor
DLS - Data Link Server

- Site A: Legacy CC
- Site B: New EMS
- Site C: Legacy CC
- Site D: New EMS

CNP - Comm. Node Processor
DLS - Data Link Server

RS 232C
ICCP Associations

- ACSE used to establish associations
- Established between two ICCP end nodes
- Typically long running
- QOS attribute for each association
  - Includes priority, transit delay, throughput, residual error rate, and protection
  - Used by OSI Network layer
- At least one association per QOS value
- ICCP client chooses proper association
Client = requester of data or service
Server = provider of data or service

Note: Client “pull”, not server “push”
I.e., not publisher/consumer model
ICCP Object Models

ICCP Server Objects

Operations

- Association
- Data Value
- Data Set
- Transfer Set
- Account Req
- Device
- Program
- Event

Actions

- Request
- Response
- Information Report
- Event

Object Models

- Indication Point
- Information Buffer
- Account/Schedule
- Protection Equip
- Power Plant
- Control Point

Control Center Data Objects
ICCP Transactions

Client Control Center

Requests *operation*
- Get Data Value
- Get Data Set
- Start Transfer
- Select/Operate

Server Control Center

Server checks access rights

Responds to client request

Reports data sets as specified in client request *(action)*

Request

Response

Report

Report
• Each ICCP operation or action is implemented using ISO/IEC 9506 MMS
• MMS provides standardized services with standardized messages
• ICCP client *operations* are mapped onto MMS client services
• ICCP server *actions* are mapped onto MMS server services
• ICCP data objects are mapped to MMS Types