GRID PROTECTION ALLIANCE

Grid Solutions Framework Overview

GPA User's Forum 2015

Atlanta, Georgia

GPA Products

- Grid Solutions Framework
  - openPDC
  - substationSBG
  - SIEGate
  - openHistorian
  - openXDA
  - PDQTracker
  - Synchrophasor Stream Splitter
  - Project Alpha
  - PMU Connection Tester
  - GEP Subscription Tester
  - *More…*

GPA Project Relationships

Grid Solutions Framework (GSF)

http://gsf.codeplex.com/

GSF Implementations:

openPDC / openHistorian / SIEGate

http://openpdc.codeplex.com/

Multiple Open Source Projects

- Grid Solutions Framework
  - http://gsf.codeplex.com/
- Secure Information Exchange Gateway (SIEGate)
  - http://siegate.codeplex.com/
- Open Source Phasor Data Concentrator (openPDC)
  - http://openpdc.codeplex.com/
- Open Historian
  - http://openhistorian.codeplex.com/
- PMU Connection Tester
  - http://pmuconnectiontester.codeplex.com/

FYI: We are moving projects to GitHub!

Benefits of Open Source Hosting

- Project source code control
  - This directly integrates with Visual Studio
- Project contributor forks or patches
  - This allows contributors to suggest formal code updates
- Project release downloads
  - This allows us to control major releases and track downloads
- Discussion forums & mailing lists
  - This allows users to help users and request community help
- Wiki and documentation pages
  - This allows up-to-date online documentation
- Bug and feature request tracker
  - This allows users to post issues for resolution

Accessing Online Documentation

- All online documentation is continually updated by both GPA and contributors.
- Typically you need only go the project's CodePlex site in question and click the "Documentation" tab to get started with system documentation.
- For example, here is the openPDC Documentation Link - on this page you can navigate to:
  - Getting Started
  - Frequently Asked Questions
  - Major Component Overviews
  - How-to Guides, etc.

GPA Development Framework

Grid Solutions Framework

GSF

Grid Solutions Framework (GSF)

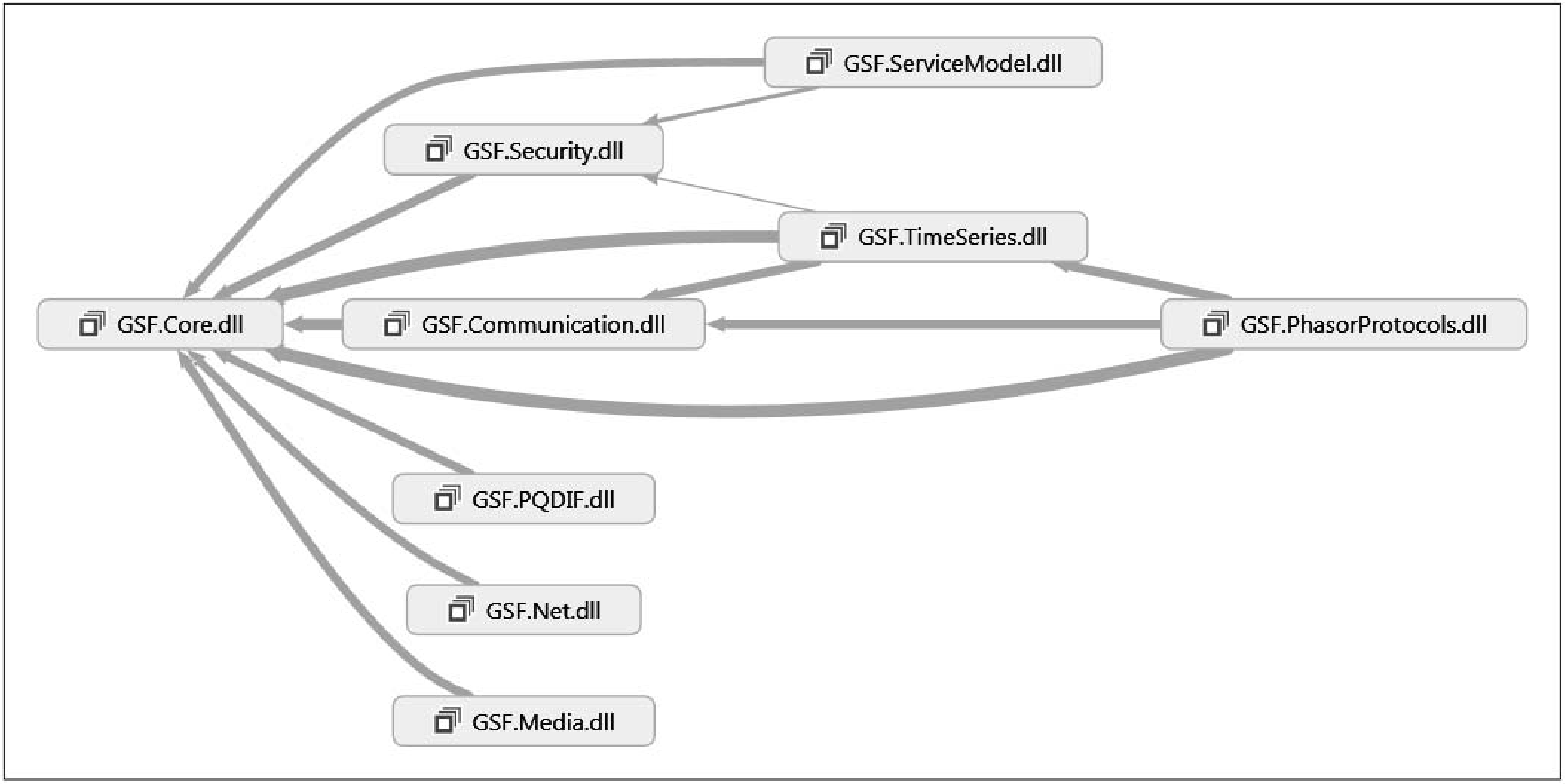
- A software development platform that was initially created as a combination of the Time-Series Framework and the TVA Code Library with a goal to increase performance and security
- Full namespace refactoring and projects targeted to compile with the Microsoft .NET 4.5 Framework. Will soon target 4.6.
- New core features and improvements are only implemented in the GSF (only a few bug fixes flowed back to the original projects)

http://gsf.codeplex.com/

Grid Solutions Framework Purpose

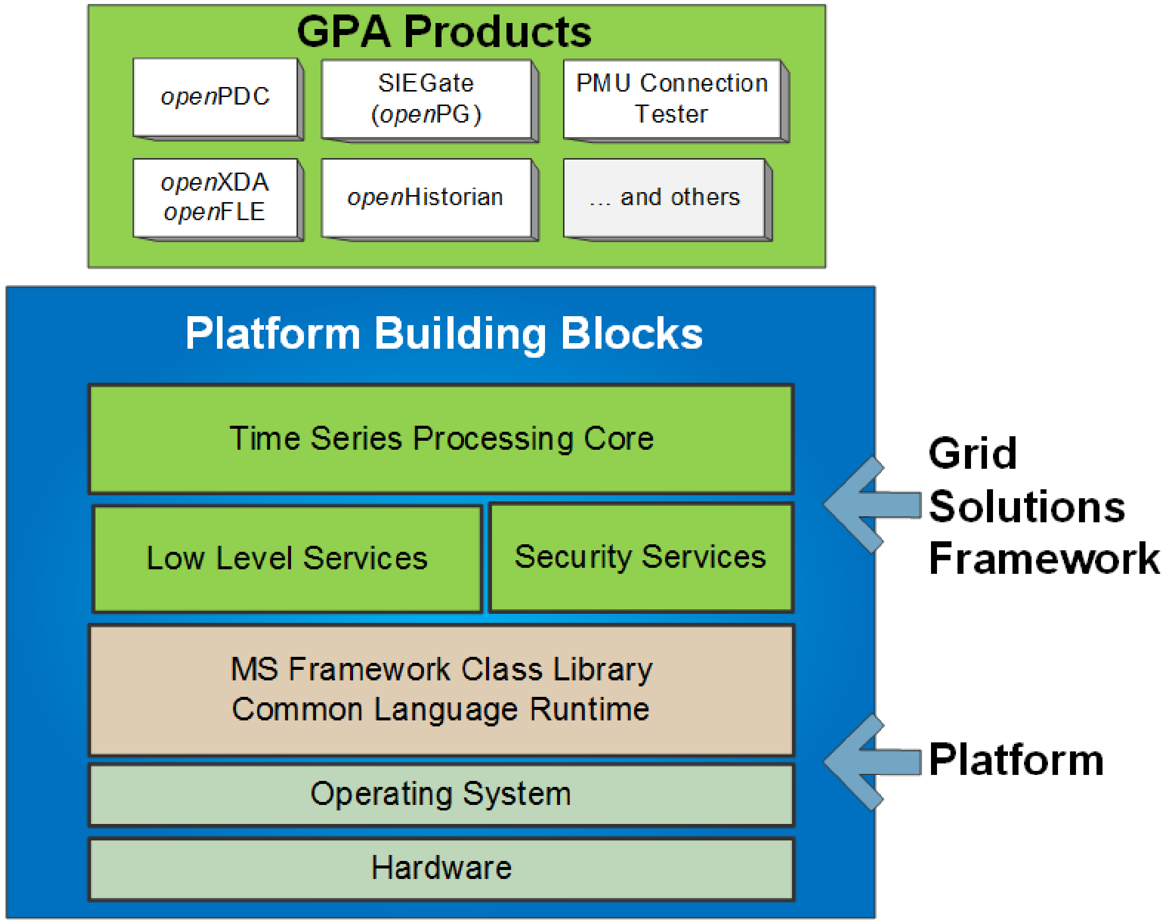
- General purpose open source library of .NET code used by many utilities and various open source projects that contains a large variety of code useful for nearly any .NET project.
- Consists of hundreds of classes that extend and expand the functionality included in the .NET Framework making more complex .NET features easier to use and adds functions not included in the .NET Framework.
- Used since it provides a standard development platform, improves development speed and increases reliability.

GSF Primary Assemblies



~70 Assemblies Spanning ½ Million Lines of Code and Over 150K Lines of Comments

Built using GSF



GSF Time-series Library

- Core collection of classes used to manage, process and respond to dynamic changes in fast moving streaming time-series data in real-time.
- Allows applications to be architected as measurement routing systems using “Input”, “Action” and “Output” adapter layer.
- Any application can host the framework which will allow a system to become a “real-time measurement bus”.

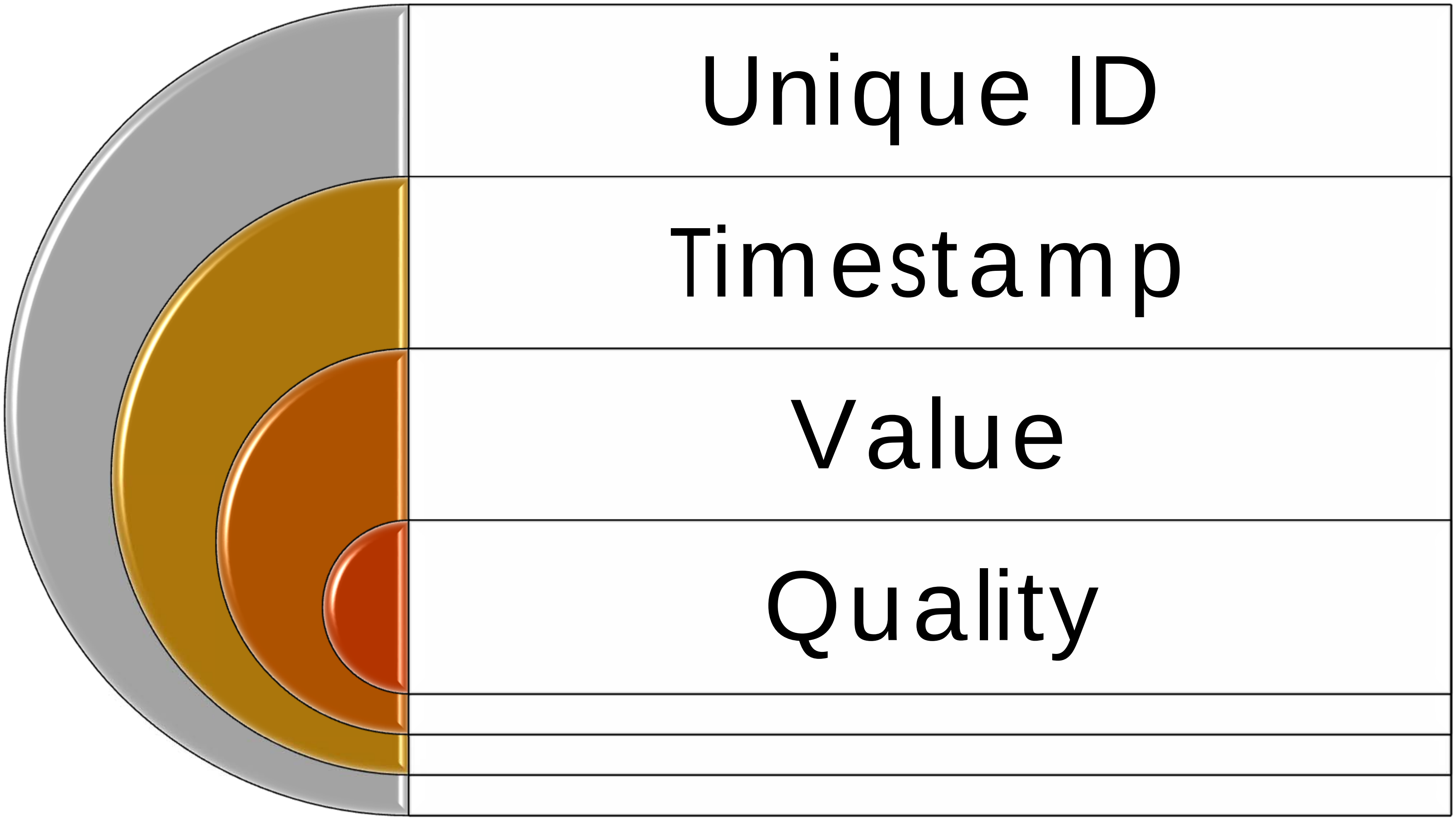
Measurements

- Numeric quantities that have been acquired at a source device are often known as points, signals, events, or time-series values. Inside GSF they are known as ***measurements***:
  - Examples include: temperature, voltage, vibration, location, luminosity and phasors.

Understanding "Measurements"

- A "measurement" as it is understood in the Grid Solutions Framework has many aliases:
  - Signal
  - Point
  - Tag
  - Time-series Value
- The primary components of the measurement are:
  - Timestamp
  - Value
  - Identification

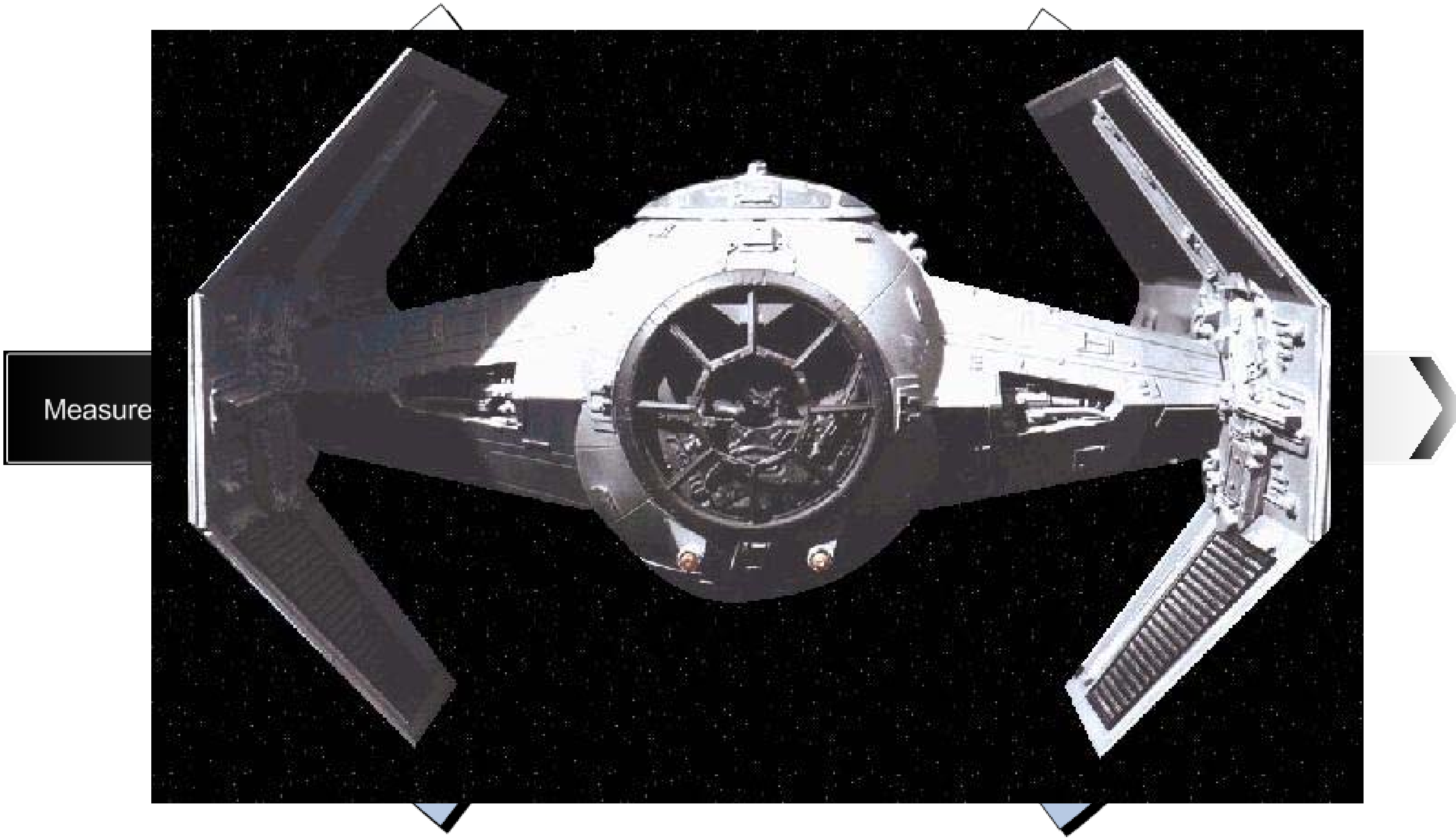
Measurement Structure



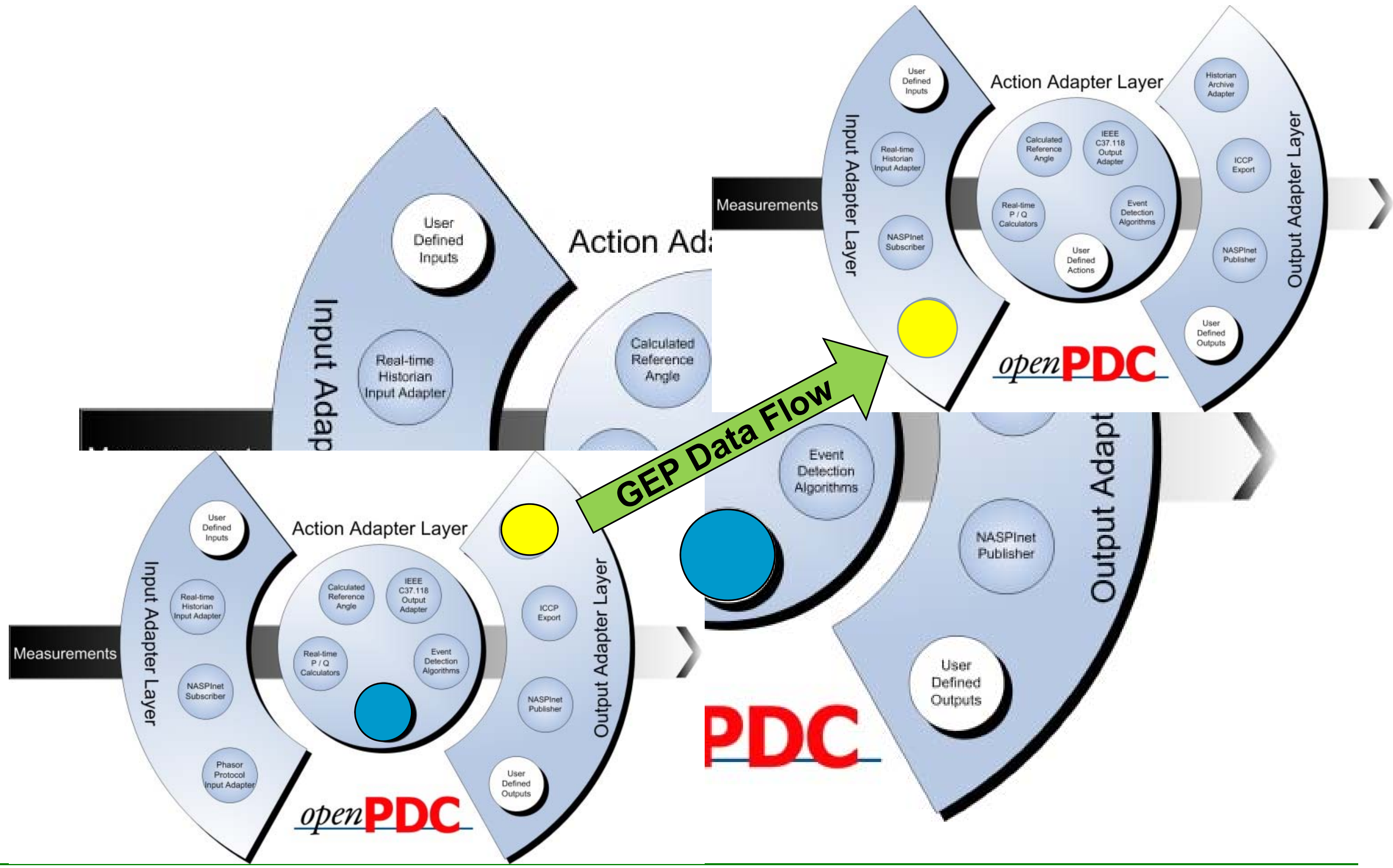
Measurement Identification

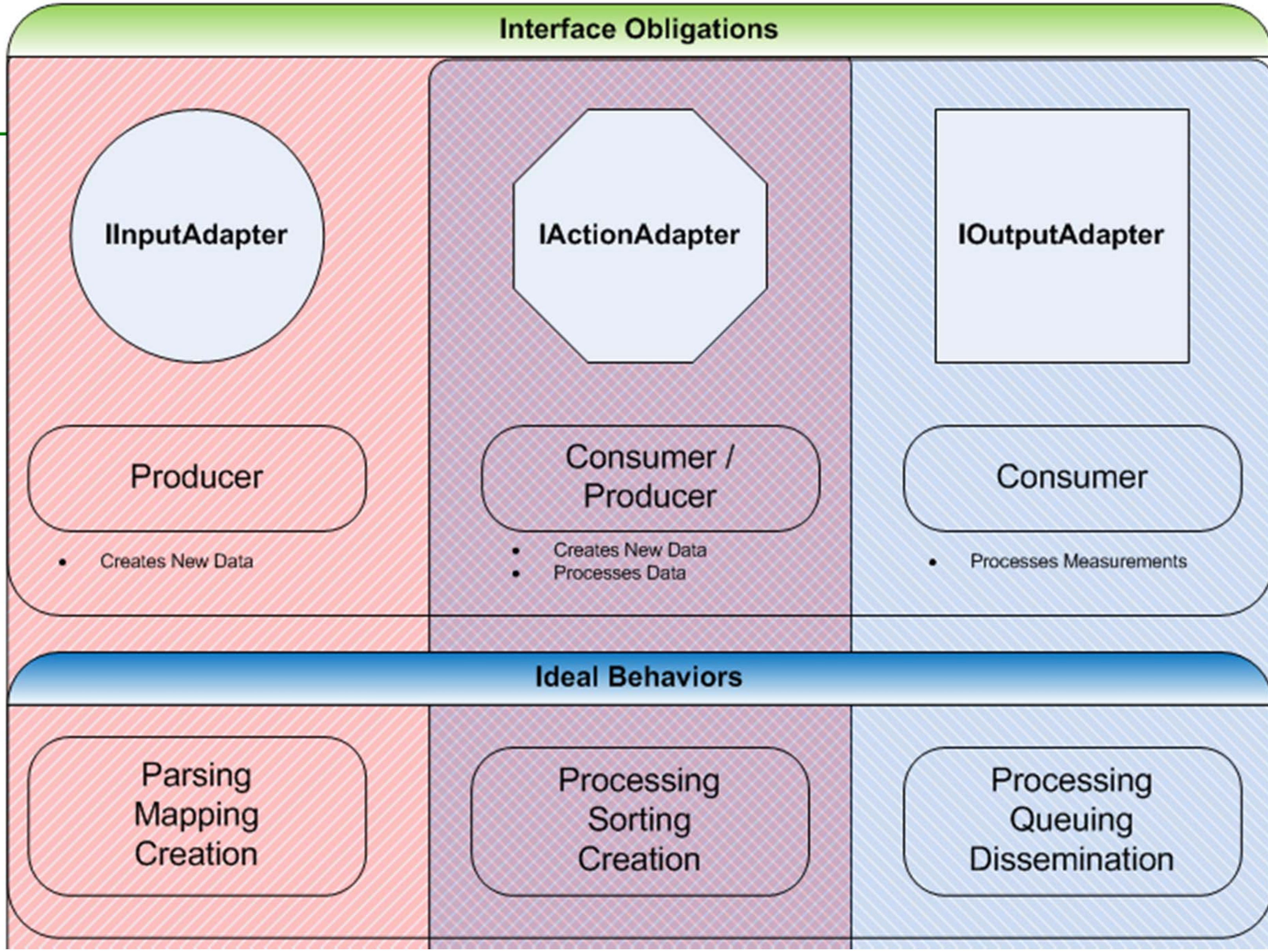
- Guid:
  - 128-bit randomly generated integer that is statistically going to be unique in the world, examples:
    - 7ACDEE91-661B-42A0-82C1-081090D0CA38
    - 532863E4-8C3A-4F84-8366-0C8A4711EA6F
    - 4E3548FD-470E-45DF-8C44-138936805BB6
- Measurement "Key":
  - Two part identifier represented by a "Source" string and a numeric "ID", examples:
    - PPA:2
    - STAT:42
    - SHELBY:39

Overview of the Adapter Architecture Layer



Scalable Adapter Distribution




Interface Obligations
IInputAdapter
IActionAdapter
IOutputAdapter
Producer
Consumer /
Producer
Consumer
Creates New Data
Creates New Data
Processes Data
Processes Measurements
Ideal Behaviors
Parsing
Mapping
Creation
Processing
Sorting
Creation
Processing
Queuing
Dissemination

Input Adapters

Purpose:
MAP

- Collect and parse streaming data, assign incoming measurements an ID.

Output Adapters

Purpose: **QUEUE**

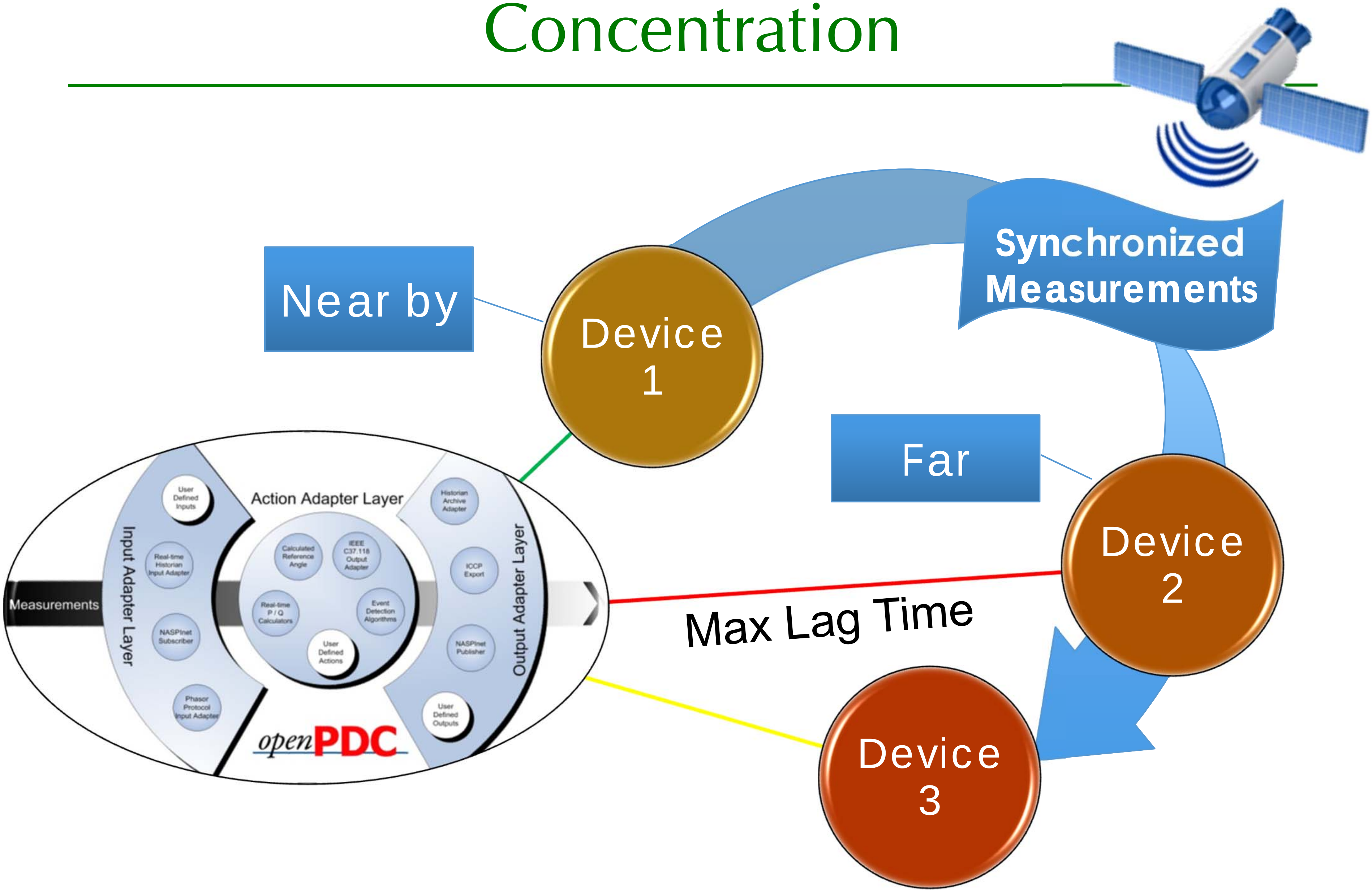
- Queue up measurement data for transmission to archival systems.

Action Adapters

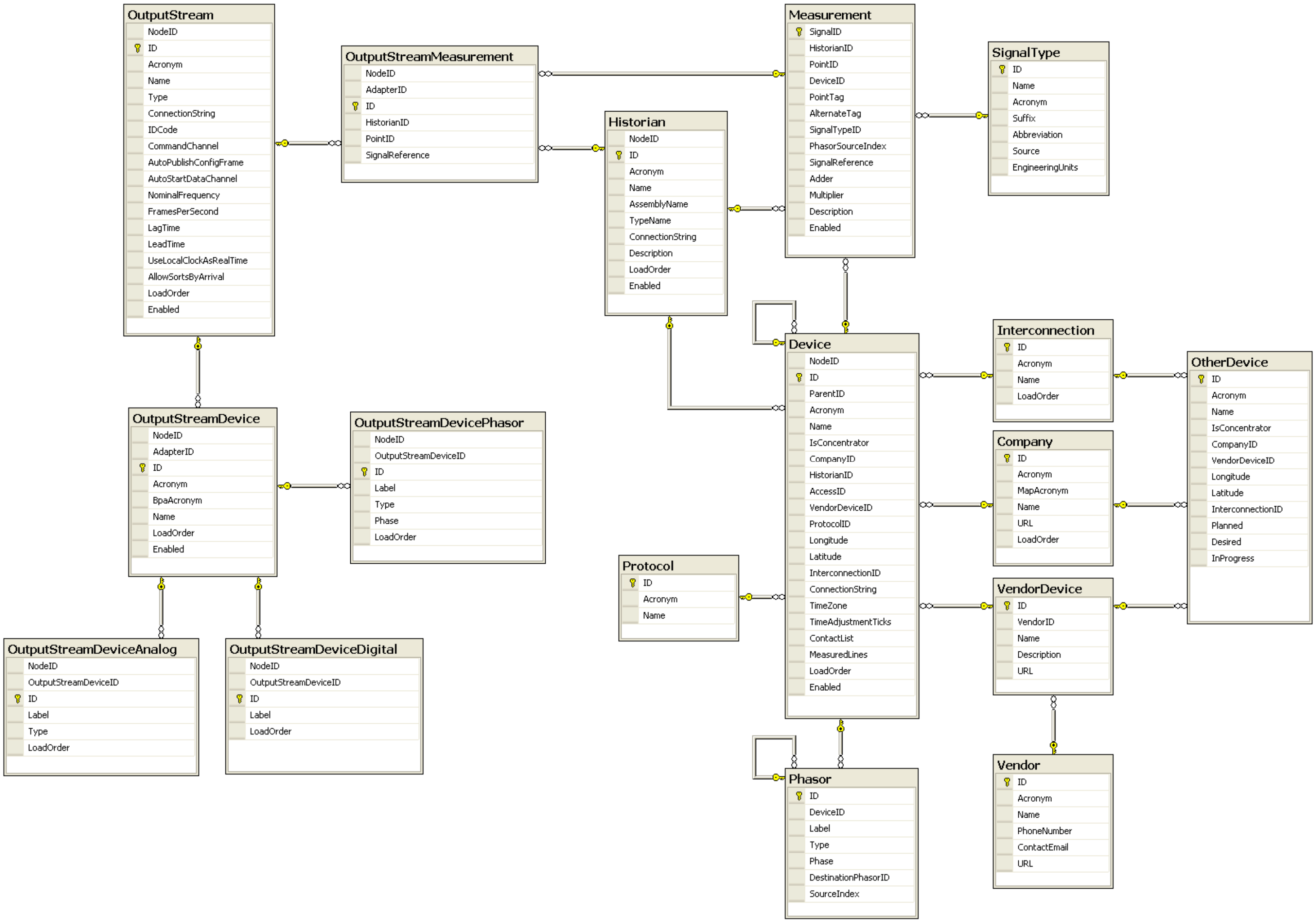
Purpose: **SORT**

- Sort measurement data by time and process the data for same time-slice.

Concentration



The Configuration Data Structure



GSF Implementation

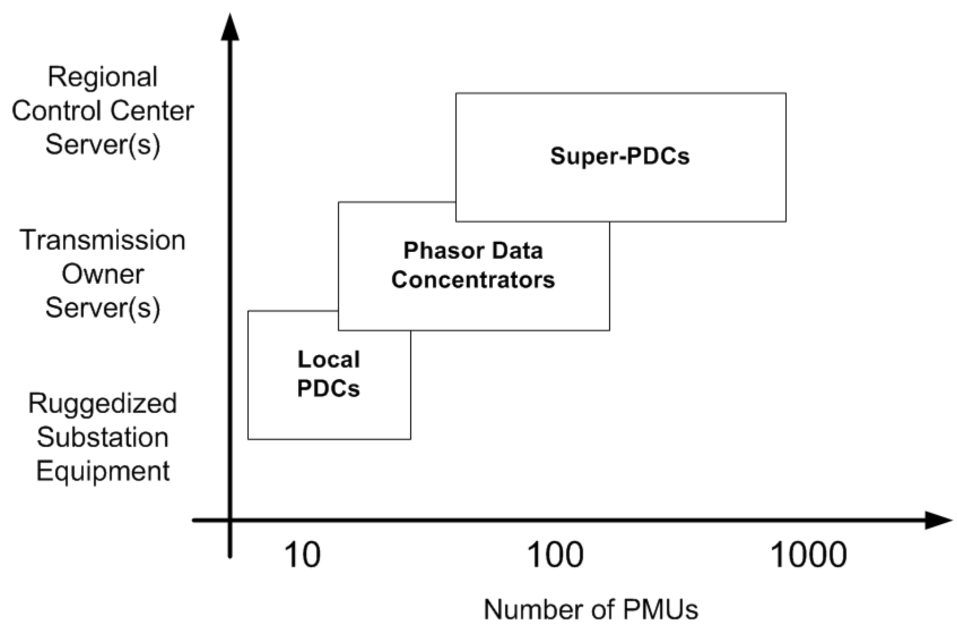
Phasor Data Concentrator

openPDC
GRID PROTECTION ALLIANCE

What is a PDC?

- *Phasor Data Concentrator (PDC)* – Receives and time-synchronizes phasor data from multiple PMUs to produce a real-time, time-aligned output data stream. A PDC can exchange phasor data with PDCs at other locations. Through use of multiple PDCs, multiple layers of concentration can be implemented within an individual synchrophasor data system.

From NERC RAPIR Report Draft, June 2010



How is a PDC typically used?

- To create a time-synchronize measurement data set
  - In the substation
  - For the Transmission Operator
  - For the Reliability Coordinator
- To distribute phasor data to applications
- To parse C37.118 for use by other systems

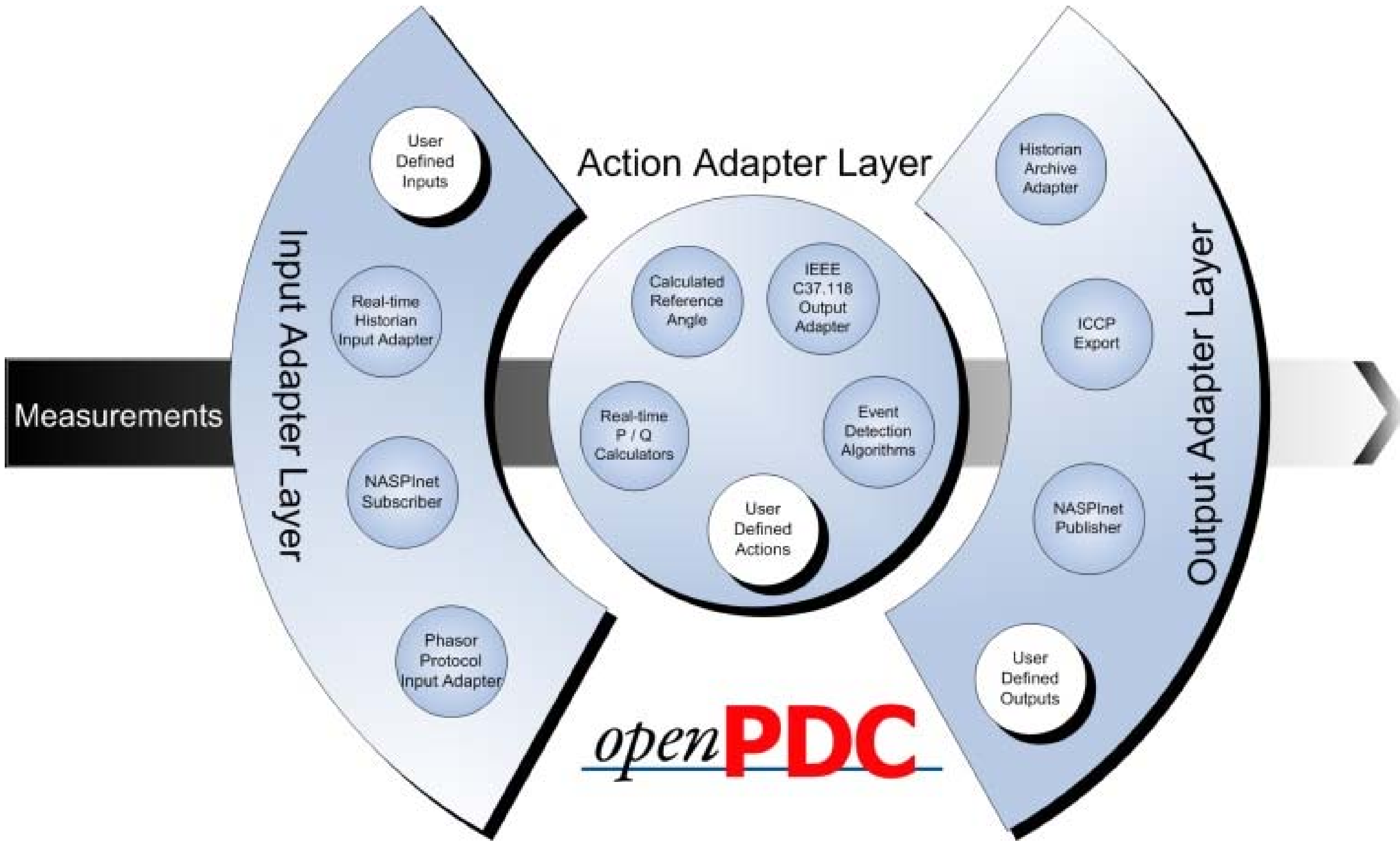
Who “touches” a PDC?

- A PDC is like an RTU-Data Concentrator for a SCADA system
- PDC’s are back-office tools, administered by specialists, that are likely to soon be part of critical infrastructure
- For compliance and good configuration control, PDC change is tightly managed

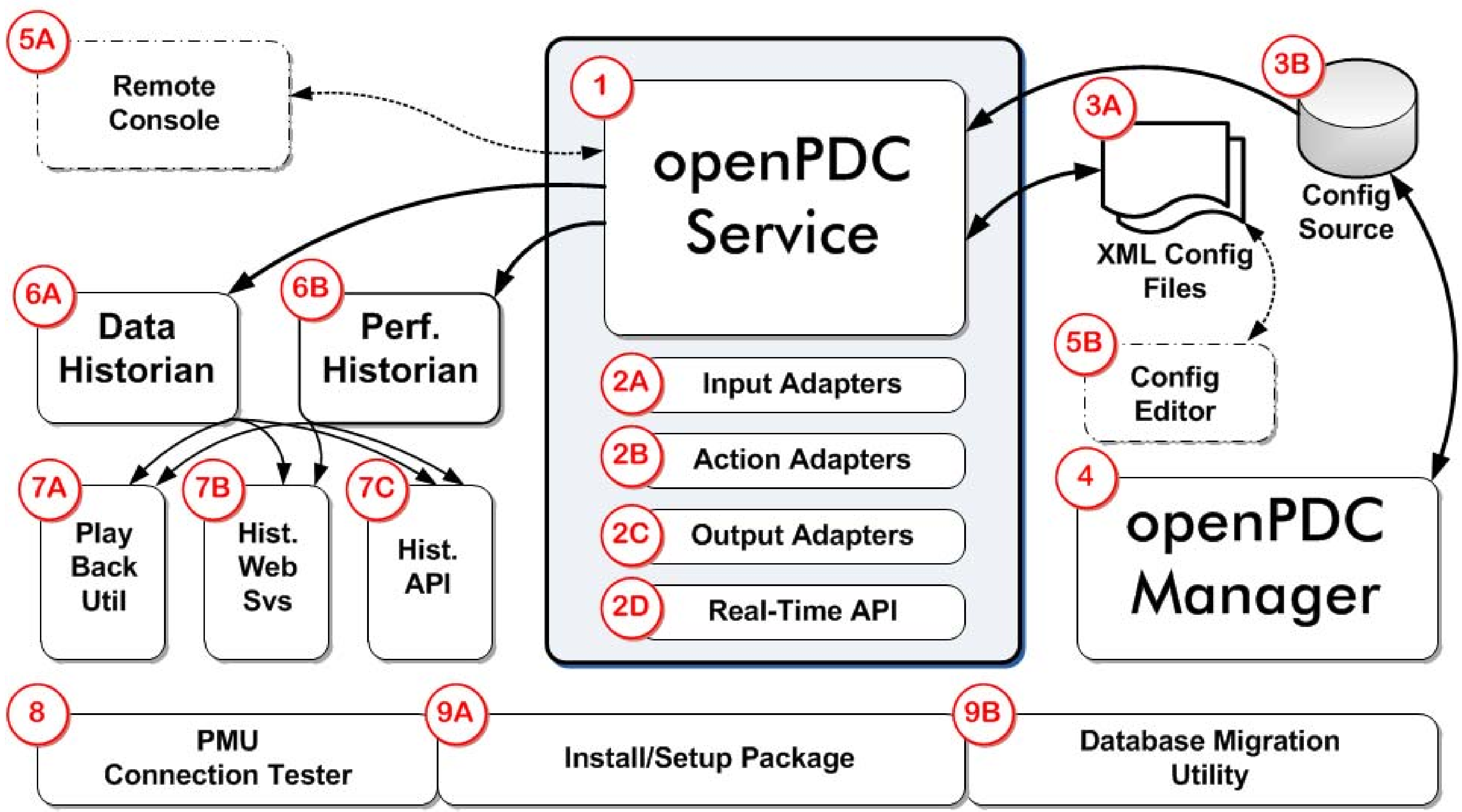
Who are some PDC Vendors?

- GPA – openPDC
- Alstom Grid – openPDC & Psymetrix
- Electric Power Group – ePDC
- Schweitzer
- General Electric
- Kalkitech

openPDC is adapter based



openPDC Components



openPDC Features

- High performance for the largest of installations
- Extreme configuration flexibility
- Preserves data integrity of incoming data streams
- Produces down-sampled real-time data streams
- Independently handles real-time and archival functions
- Horizontally and vertically scalable
- Low-latency, preemptive frame publishing
- Included performance historian logs highly granular operational statistics
- Extensible through the creation of input, action or output adapters
- Many instances can be remotely configured through a single configuration application
- A growing and active open source community

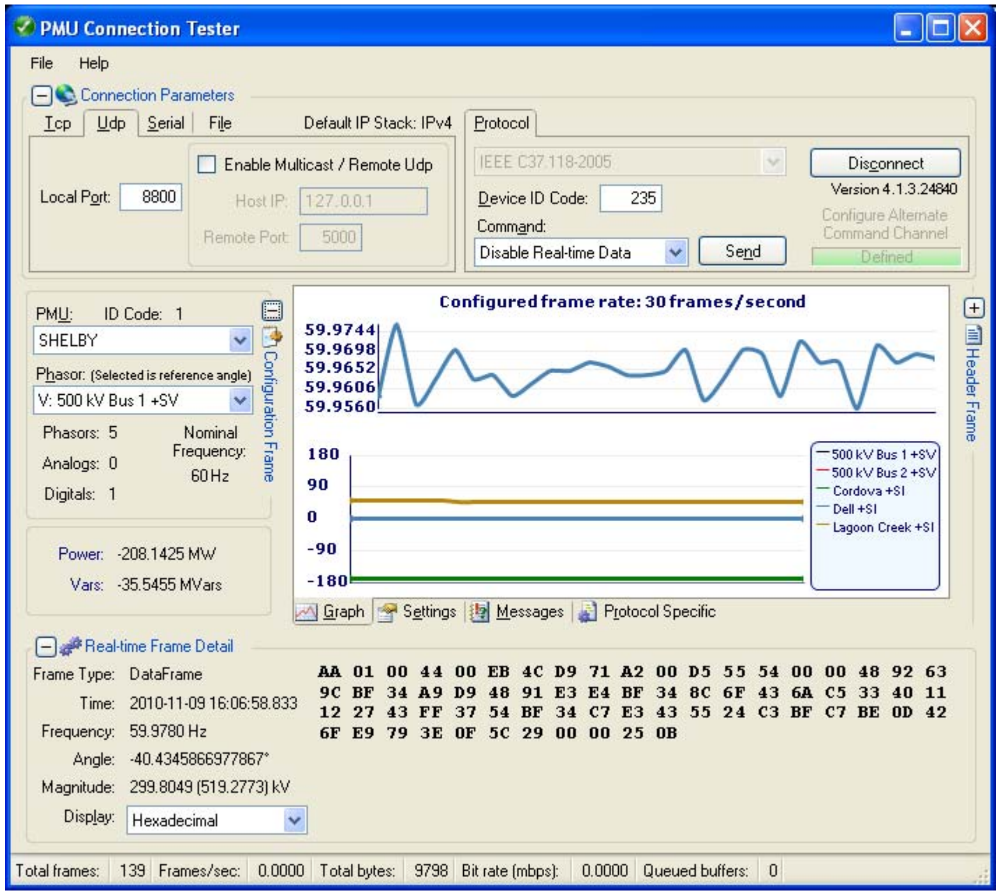
openPDC Specifications

- Input Protocols
  - IEEE C37.118-2005
  - IEEE C37.118-2011 (Beta)
  - IEC 61850-90-5
  - SEL Fast Messaging
  - Macrodyne N and G
  - IEEE 1344-1995
  - BPA PDC Stream
  - UTK FNET
  - DNP3 (Beta)
  - Gateway Exchange Protocol (GEP)
- Output Protocols
  - IEEE C37.118-2005
  - BPA PDC Stream
  - Gateway Exchange Protocol (GEP)
  - Inter-Site Data (ISD) purchased from Alstom Grid

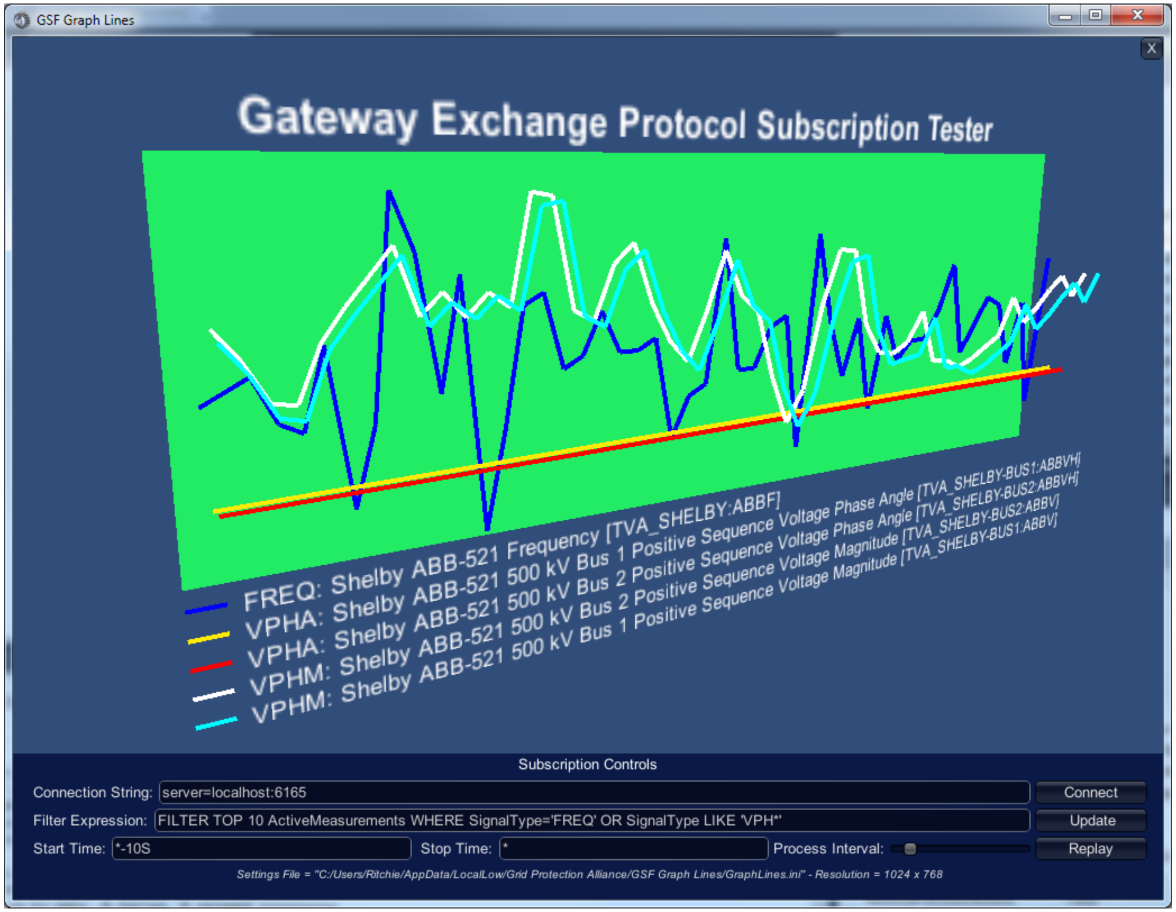
openPDC Specifications
(continued)

- Communications Standards
  - TCP – IPv4 and IPv6
  - UDP Unicast and Multicast, IPv4 and IPv6
  - Serial (input only)
- Operating System
  - Windows Server 2008, R2 recommended
- Hardware Requirements
  - Multi-processor / multi-core systems recommended
  - Tested on single core, fanless systems with as little as 2 GB of RAM
- Configuration System
  - A relational database is recommended to house configuration data. Supported databases are:
    - MS SQL Server
    - MySQL
    - Oracle
    - SQLite

Includes PMU Connection Tester



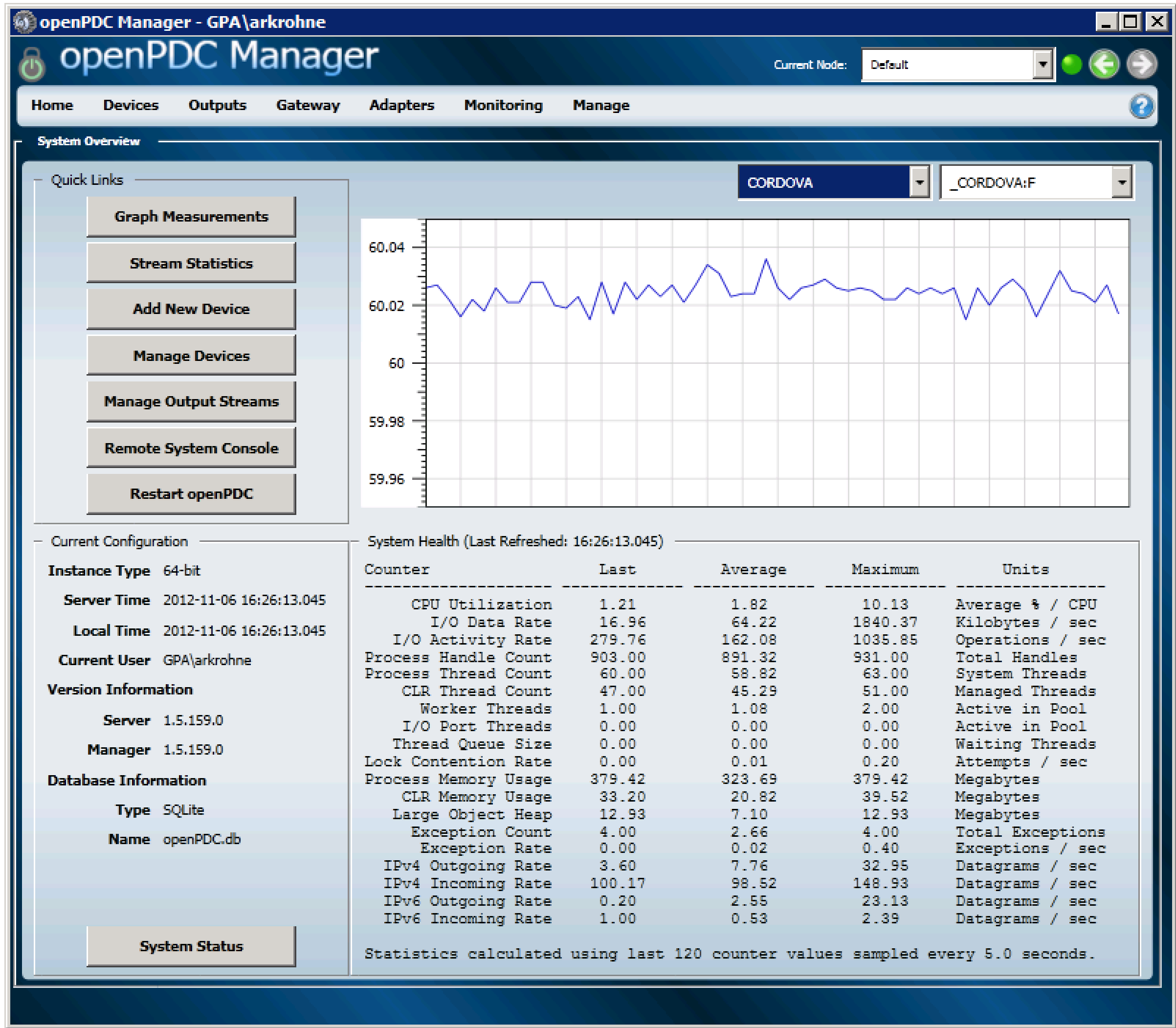
Includes GEP Subscription Tester



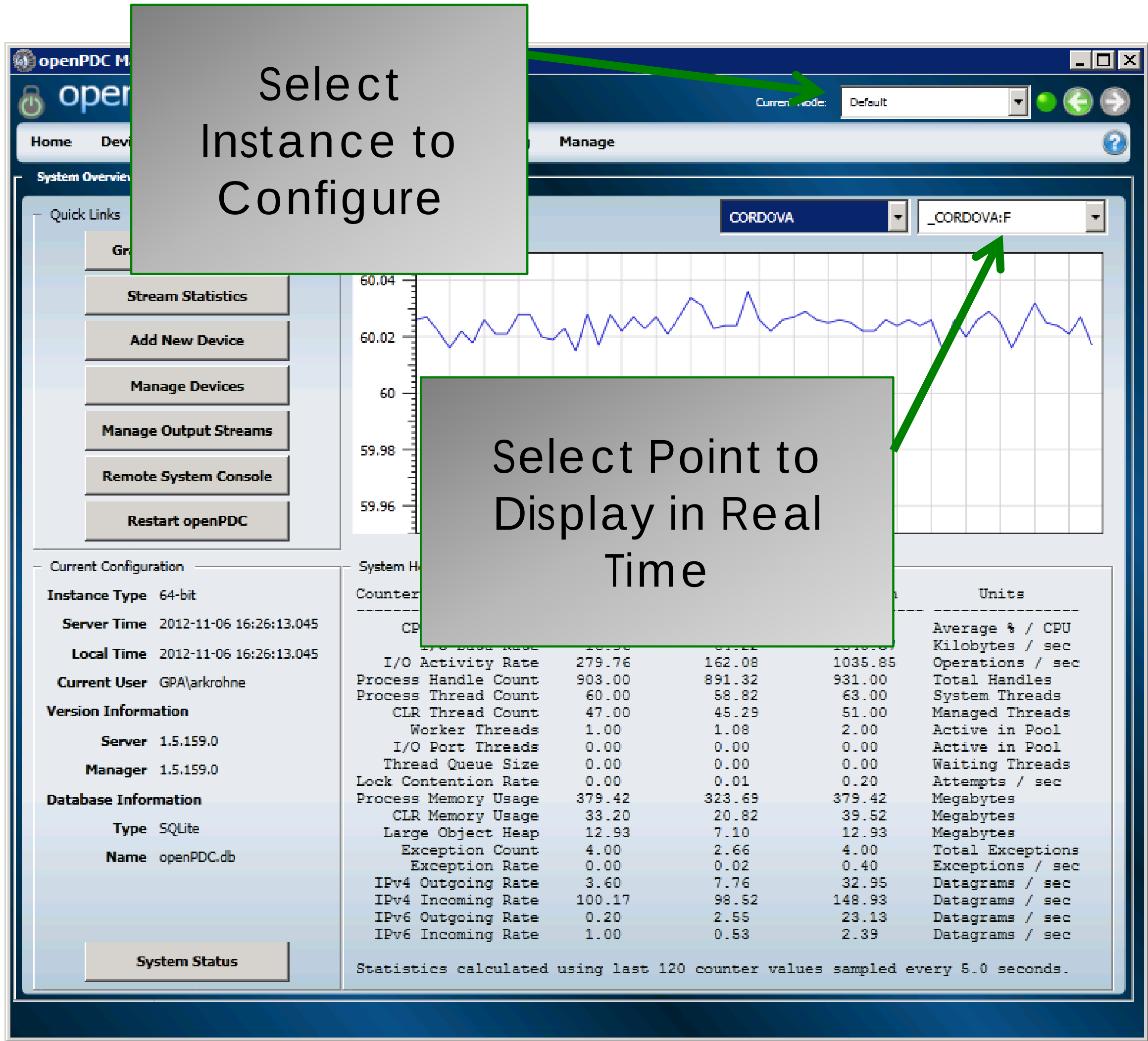
Who else uses the openPDC?

- In operational service at TVA since 2004
- Other North American production deployments include PeakRC, OG&E Dominion, Southern Company, Duke, ISO-NE, FP&L, AESO, SDG&E, PG&E and others
- Large community. There have been over 2,000 downloads of the openPDC since version 1.5 was released.

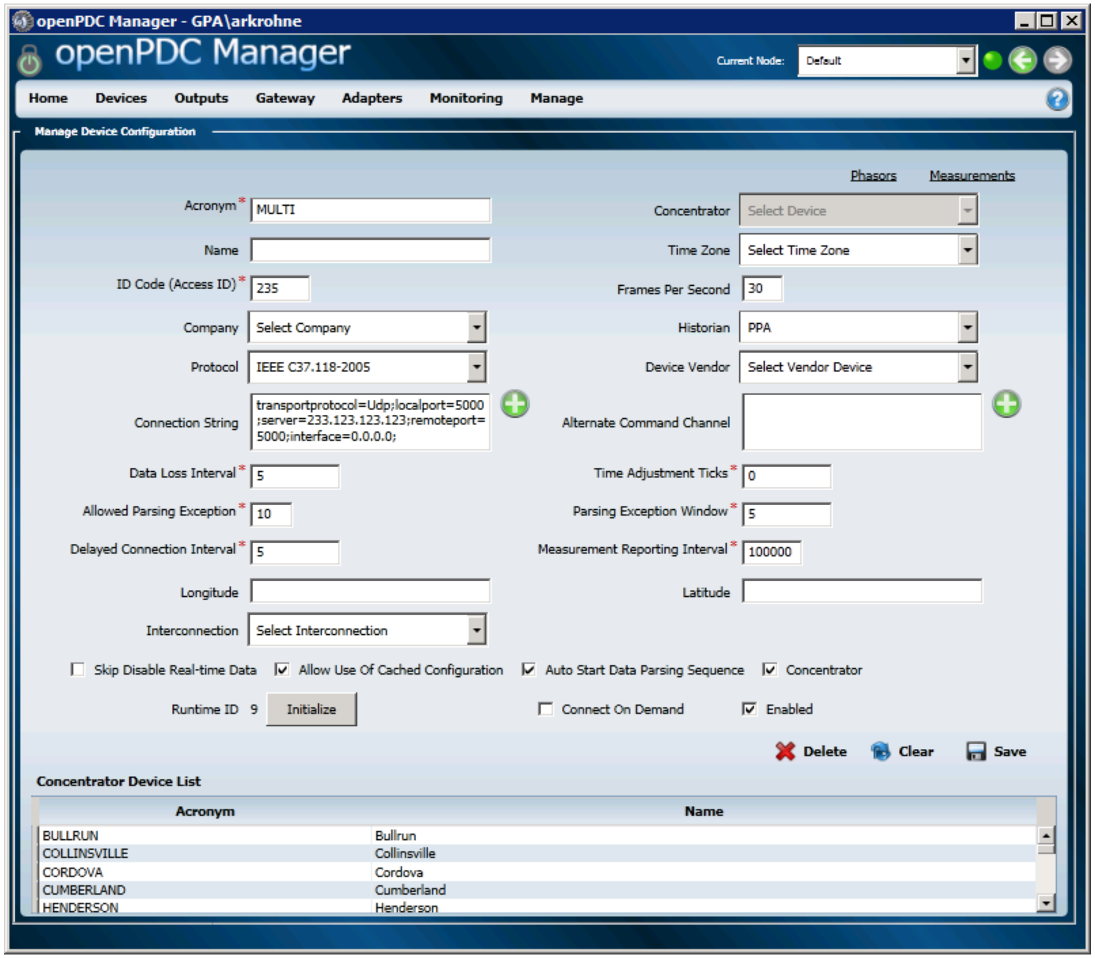
openPDC Manager Home Screen



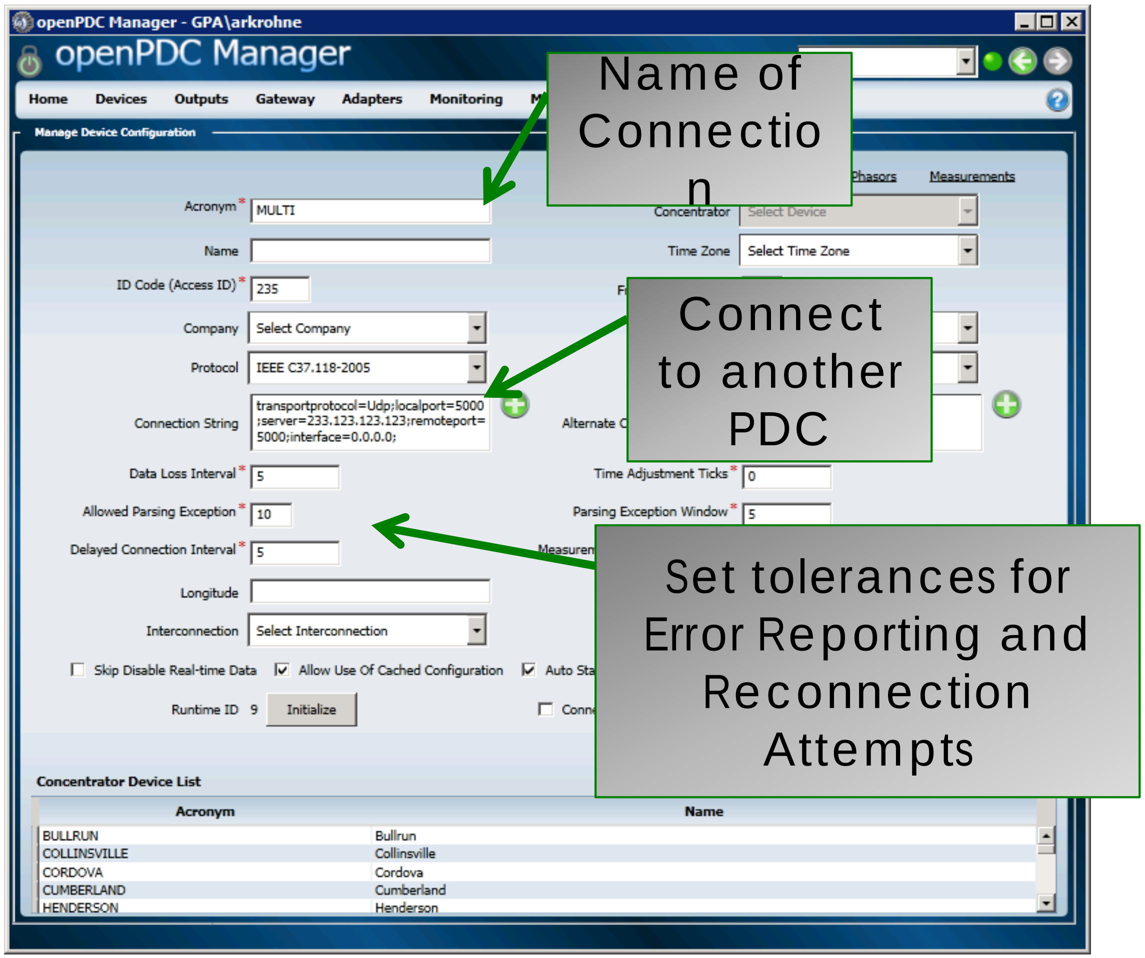
openPDC Manager Home Screen



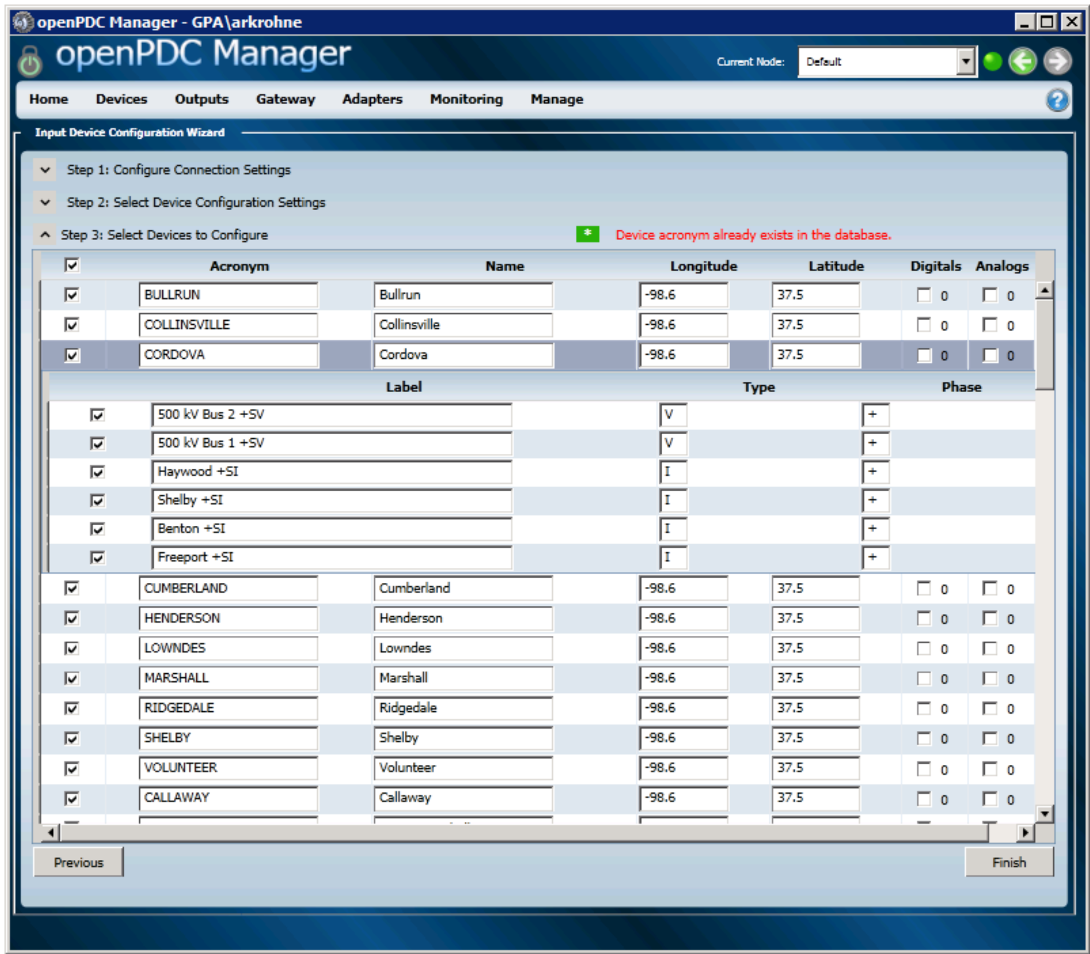
Connect to a Device



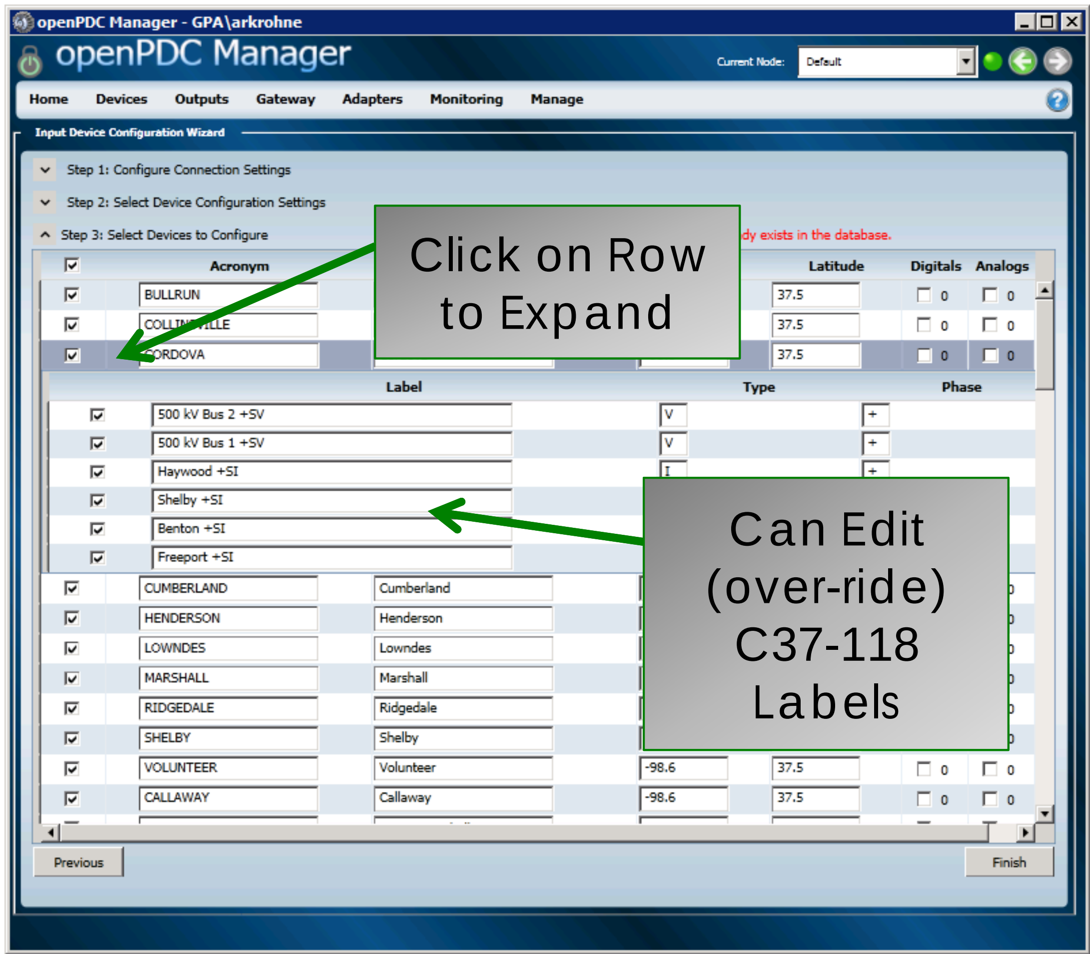
Connect to a Device



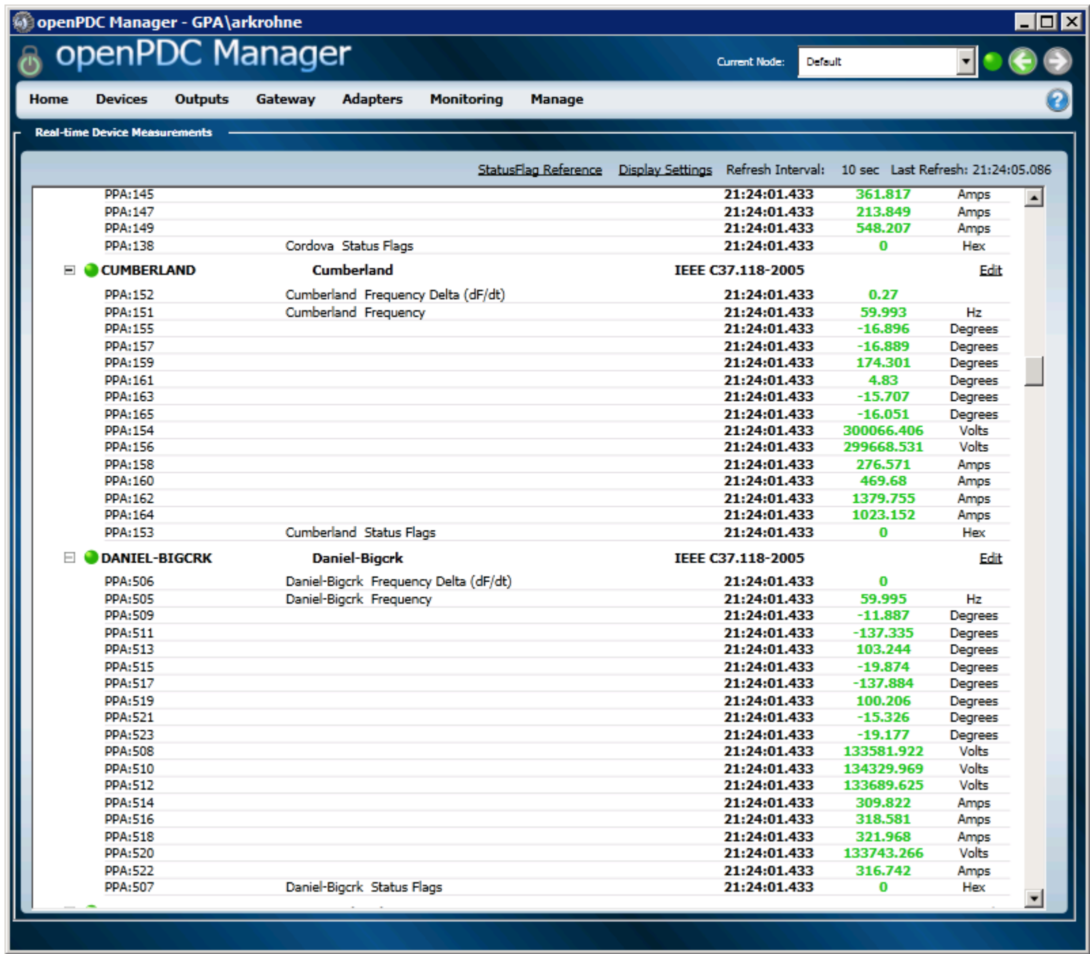
Input Configuration



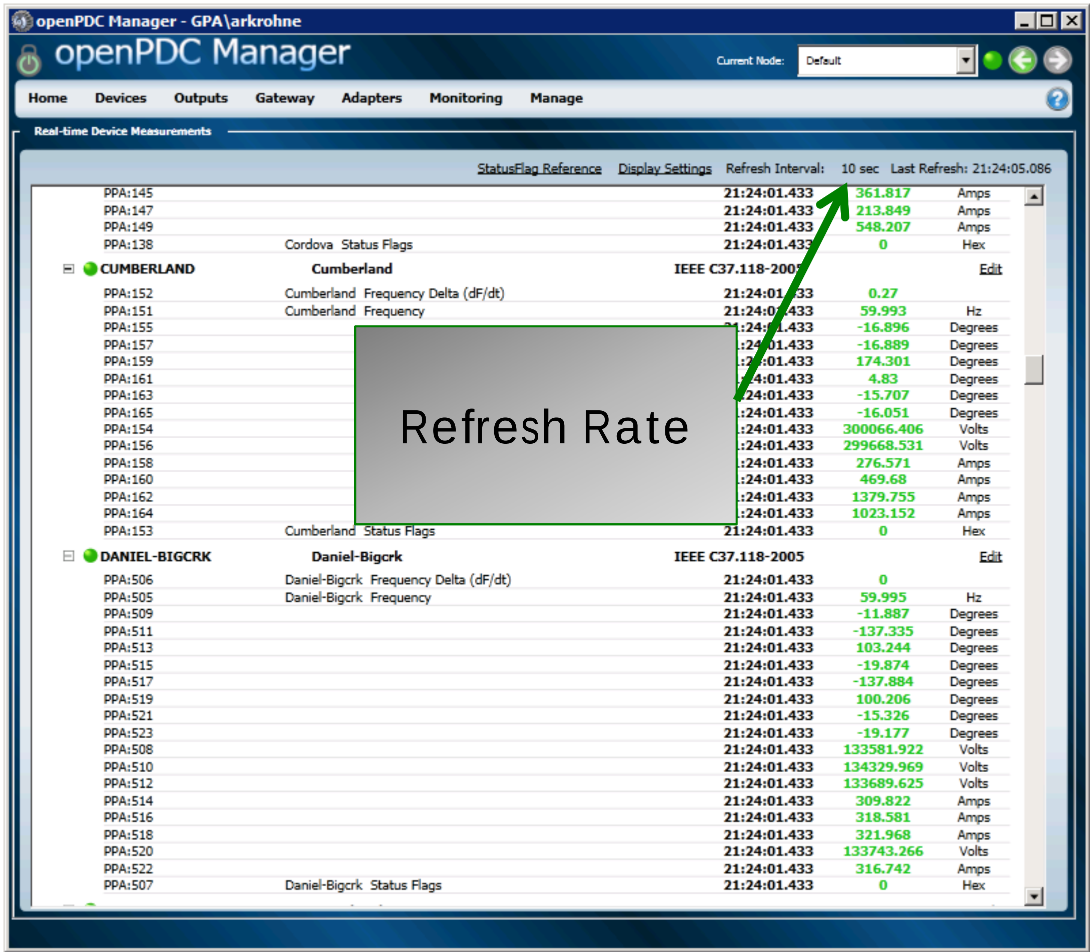
Input Configuration



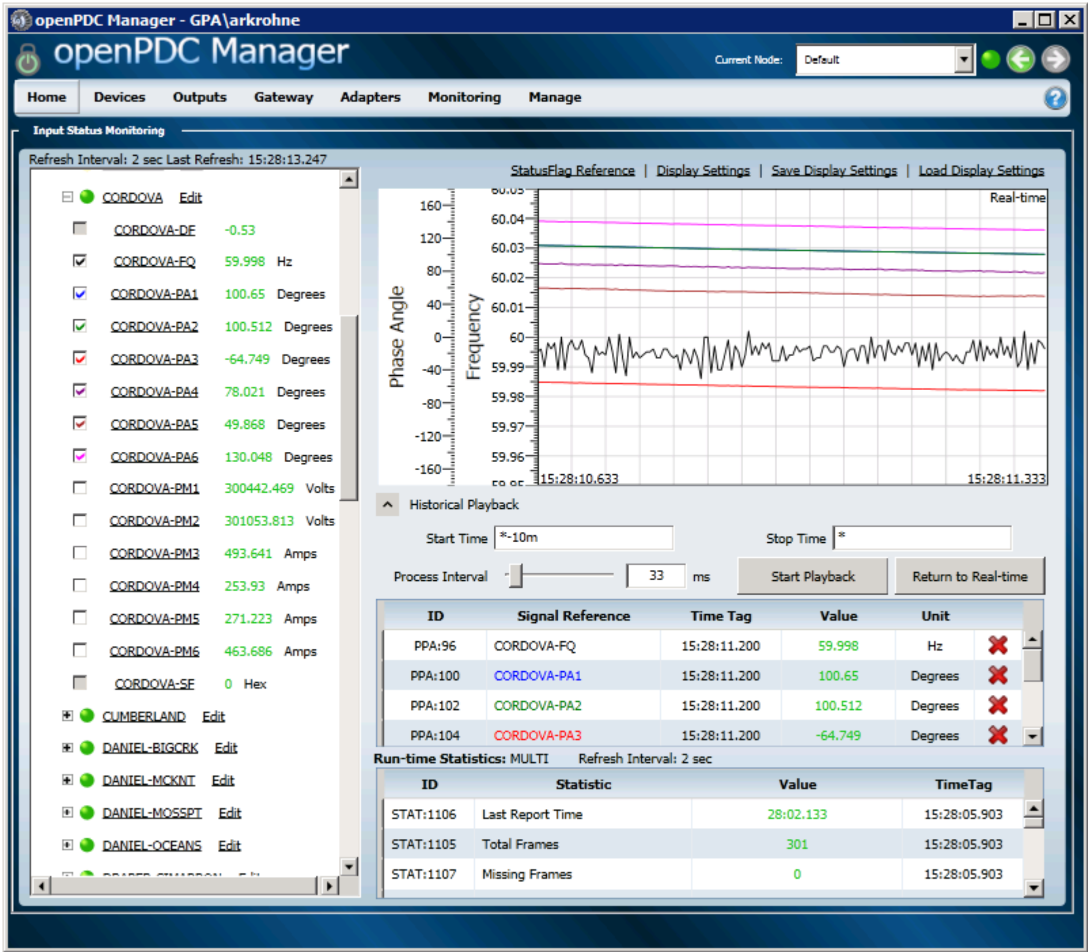
Review Real Time Values



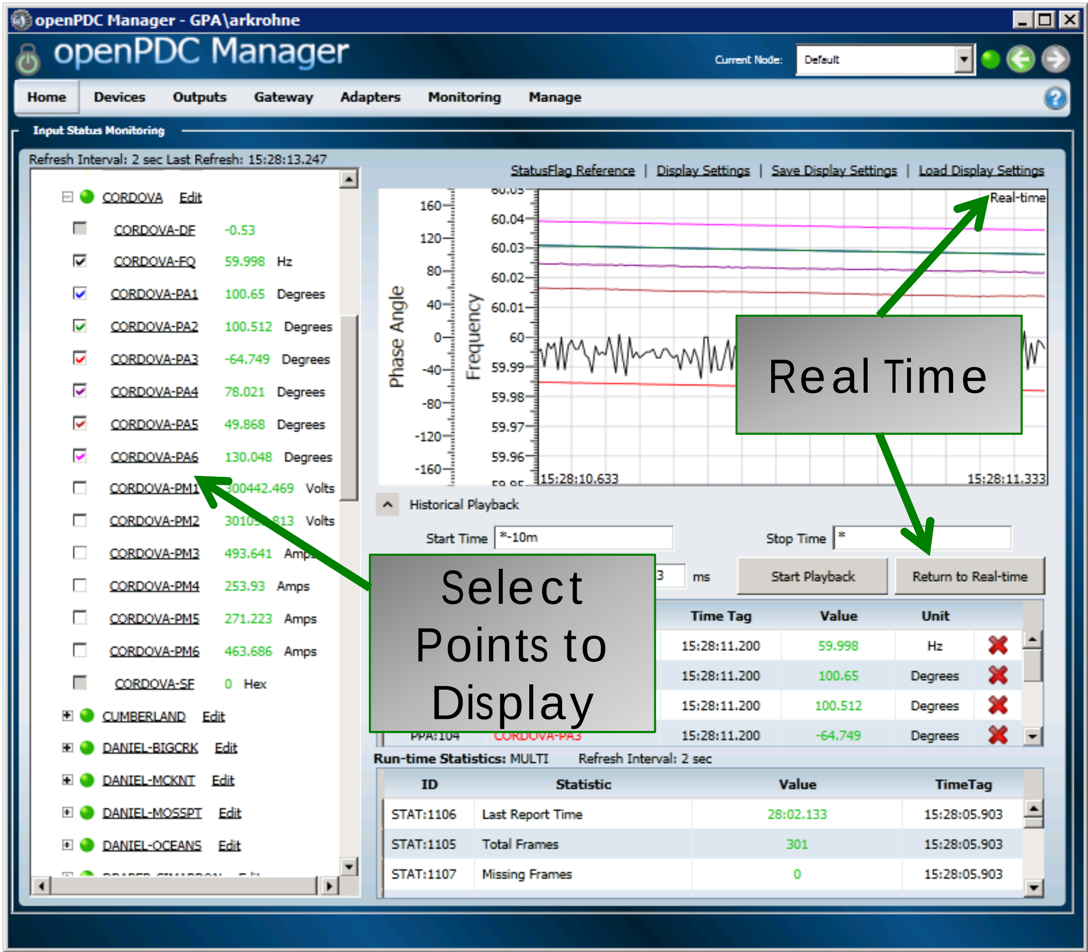
Review Real Time Values



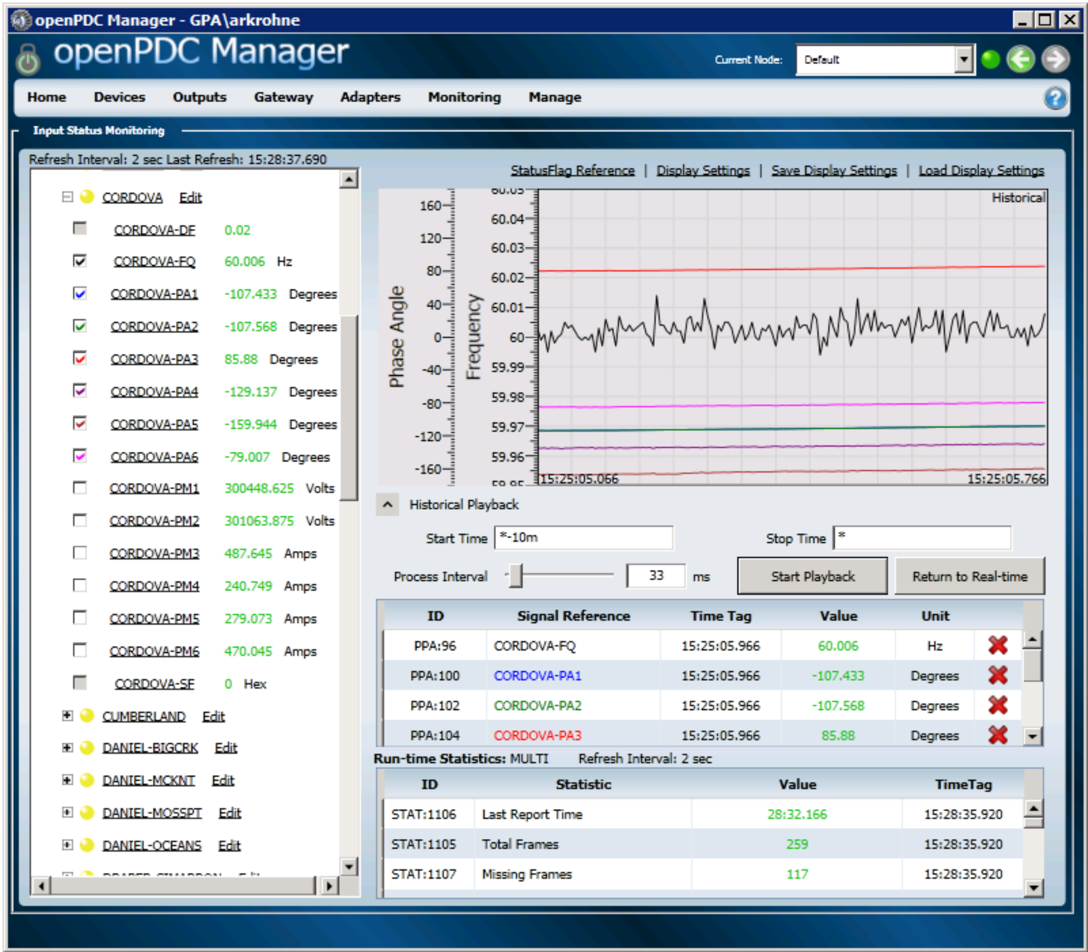
View Real Time Data



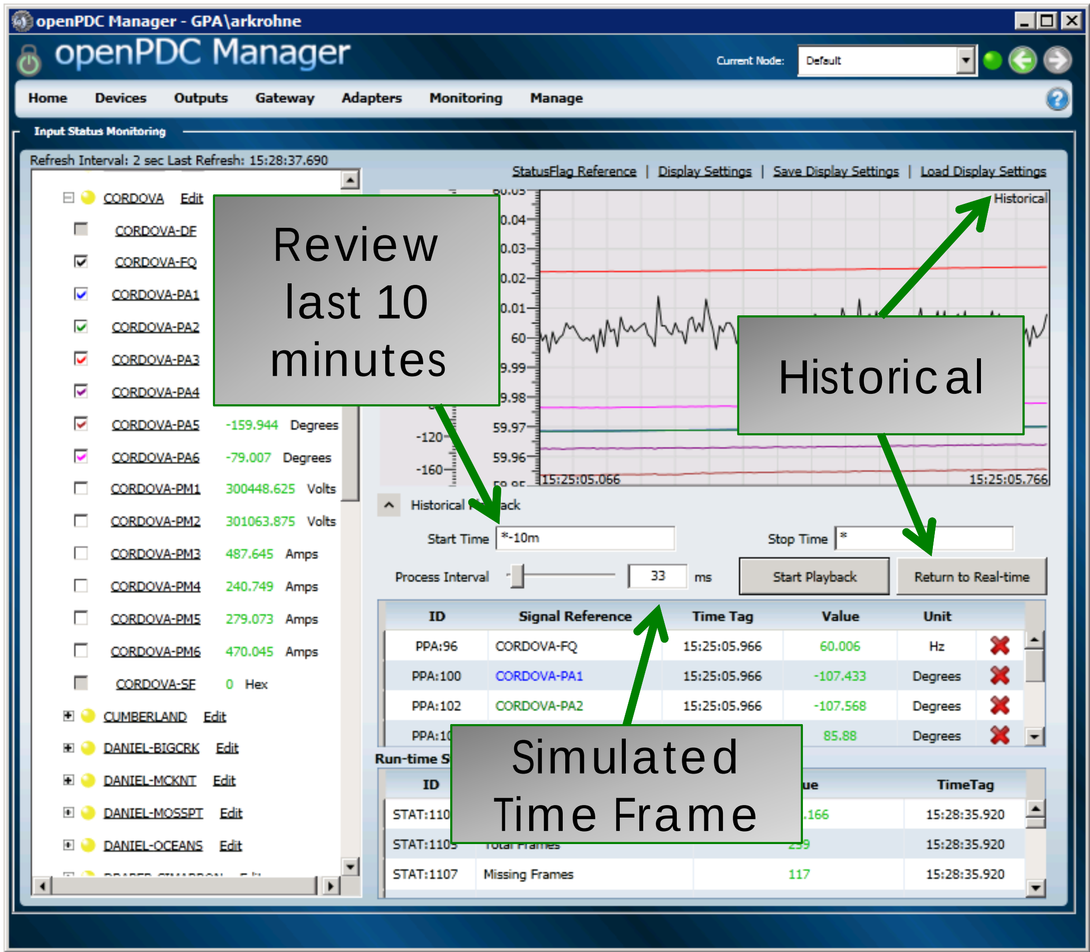
View Real Time Data



View Historical Data

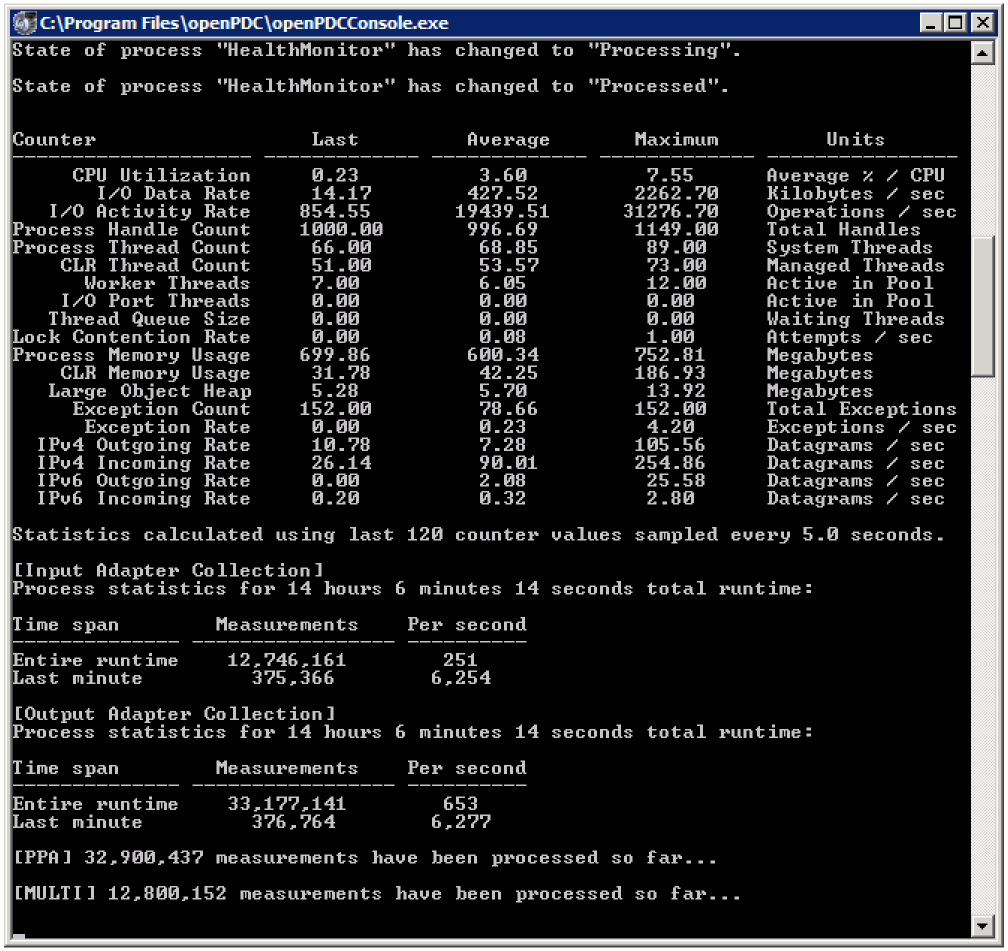


View Historical Data



openPDC Console

- The openPDC console can be used to remotely monitor the details of openPDC operation
- It can be run independently of the openPDC Manager
- Typical Commands
  - **Clients** Shows list of connections to service
  - **Health** Shows health report
  - **List** Displays list of devices connections
  - **Help** Displays list of commands



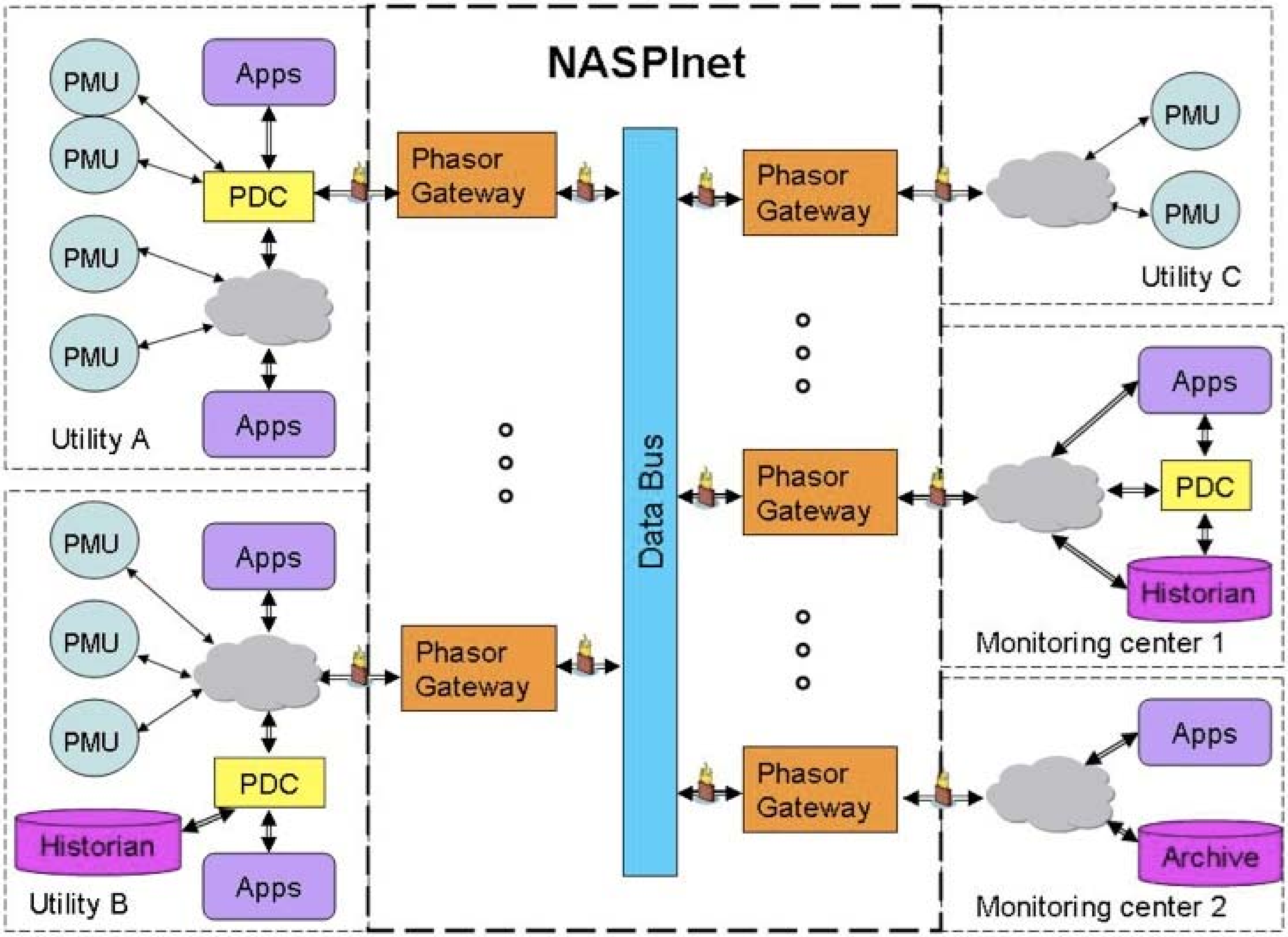
```
C:\Program Files\openPDC\openPDCConsole.exe
State of process "HealthMonitor" has changed to "Processing".

State of process "HealthMonitor" has changed to "Processed".


Counter                    Last         Average       Maximum         Units
--------------------   ------------  ------------  ------------  ----------------
     CPU Utilization       0.23          3.60          7.55      Average % / CPU
       I/O Data Rate      14.17        427.52       2262.70      Kilobytes / sec
   I/O Activity Rate     854.55      19439.51      31276.70      Operations / sec
Process Handle Count    1000.00        996.69       1149.00      Total Handles
Process Thread Count      66.00         68.85         89.00      System Threads
    CLR Thread Count      51.00         53.57         73.00      Managed Threads
      Worker Threads       7.00          6.05         12.00      Active in Pool
    I/O Port Threads       0.00          0.00          0.00      Active in Pool
   Thread Queue Size       0.00          0.00          0.00      Waiting Threads
Lock Contention Rate       0.00          0.08          1.00      Attempts / sec
Process Memory Usage     699.86        600.34        752.81      Megabytes
    CLR Memory Usage      31.78         42.25        186.93      Megabytes
   Large Object Heap       5.28          5.70         13.92      Megabytes
     Exception Count     152.00         78.66        152.00      Total Exceptions
      Exception Rate       0.00          0.23          4.20      Exceptions / sec
  IPv4 Outgoing Rate      10.78          7.28        105.56      Datagrams / sec
  IPv4 Incoming Rate      26.14         90.01        254.86      Datagrams / sec
  IPv6 Outgoing Rate       0.00          2.08         25.58      Datagrams / sec
  IPv6 Incoming Rate       0.20          0.32          2.80      Datagrams / sec

Statistics calculated using last 120 counter values sampled every 5.0 seconds.

[Input Adapter Collection]
Process statistics for 14 hours 6 minutes 14 seconds total runtime:

Time span         Measurements      Per second
--------------  ----------------  ----------
Entire runtime     12,746,161          251
Last minute           375,366        6,254

[Output Adapter Collection]
Process statistics for 14 hours 6 minutes 14 seconds total runtime:

Time span         Measurements      Per second
--------------  ----------------  ----------
Entire runtime     33,177,141          653
Last minute           376,764        6,277

[PPA] 32,900,437 measurements have been processed so far...

[MULTI] 12,800,152 measurements have been processed so far...
```

GSF Implementation

Secure Information Exchange Gateway

SIEGate

The term "Gateway" came from NASPInet

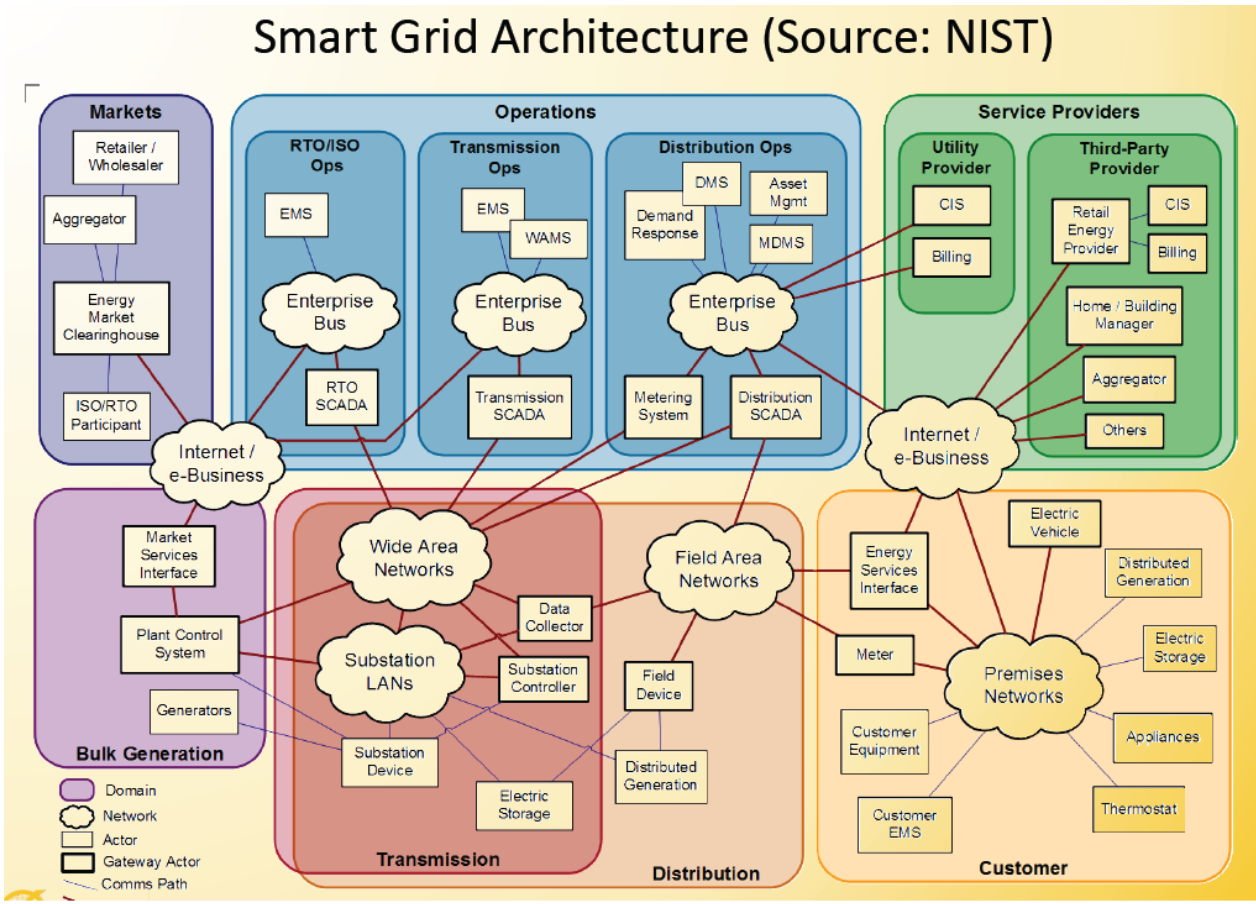


Taken from NASPInet Specification, 2007

What is a gateway?

- Creates a hardened security buffer between critical internal systems and external ones
- Protects the confidentiality and integrity of reliability and market sensitive BES data
- Facilitates and reduces the cost of BES data exchange, including synchrophasor data -- both the actual data and the supporting metadata information for this data as well

Current State of BES Data Exchange is Complex



PDC vs. SIEGate

- PDC – optimized for time-alignment of many inputs
  - Accepts inputs from PMUs and other IEDs using the broadest range of formats and protocols
  - Provides time-alignment of data (with delays and loss after time-out)
  - Allows implementation of adapters that require rapid access to time-aligned data
  - Publishes multiple time-concentrated streams
  - Reports and alarms on quality of measurements (signals) and input device status
- SIEGate – optimized for directed data transfer of granular information that facilitates a security-layered network design
  - Manages asynchronous communication of specific measurements (signals) with other SIEGate nodes
  - Relays data upon receipt without further delay
  - Can effectively manage the joining of two semantic models
  - Reports and alarms on status of communication of data with other gateways

SIEGate Objectives

To develop and commercialize a flexible appliance to enable the secure exchange of all types of real-time reliability data among grid operating entities.

SIEGate will be a security-centric edge-device that

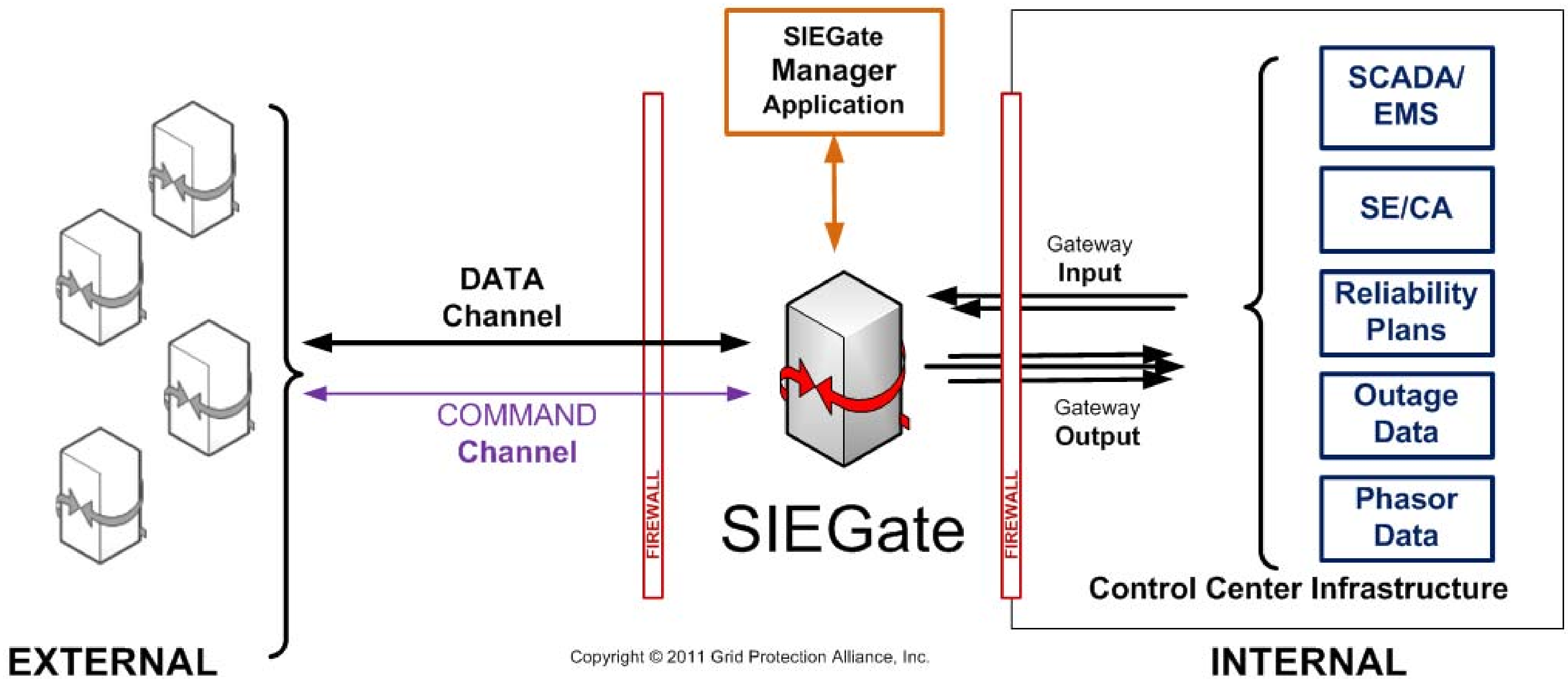
- Resists cyber attacks
- Preserves data integrity and confidentiality

and that integrates and interoperates easily with existing control room technology.

High Level Requirements

- Security Throughout
  - At multiple levels: hardware, OS, application
- High Performance
  - Meet real-time requirements
  - Scalable to meet growing capacity needs
- Support for subset of power protocols
  - DNP3, IEEE C37.118, IEC 61850-90-5, and Modbus

SIEGate Implementation



SIEGate Core Functionality

- Reliably exchange high-sample rate signal values and timestamps (measurements) with other gateways so that this information moves between with minimum time delay
- Enable gateway administrators to easily select the measurement points which are to be made available to owners of other gateways
- Enable gateway administrators to easily select the points that they chose to consume (i.e., the subset of the points made available to them) from other gateways

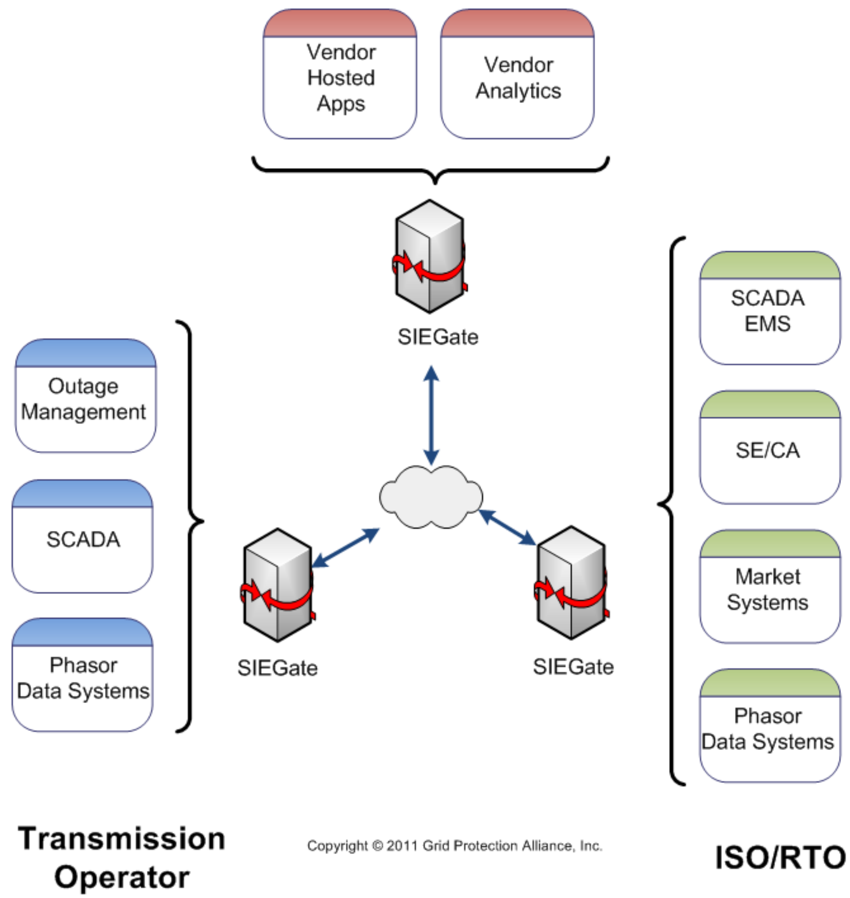
SIEGate Core Functionality

(continued)

- Detect, log and alarm on communications issues
- Be implementable as a high-availability solution that can meet NERC CIP compliance requirements
- Support encrypted communication among gateways as well as minimize bandwidth requirements for gateway-to-gateway data exchange
- Utilize standard communications, networking and server hardware
- Be easily extensible to support the development of custom interfaces to the gateway owner's internal infrastructure and/or new phasor data protocols

SIEGate Uses

- Case 1
  - RC to RC
- Case 2
  - TOp to RC
  - BA to RC
- Case 3
  - TOp to Distribution Ops
  - BA to BA
  - TOp to TOp
- Case 4
  - RC/Top/BA to Wide Area Service Provider (SANFR)



SIEGate Data Classes

- Real Time Measurements
  - Phasor Data
  - SCADA Data
- Batch Data
  - Disturbance Data
  - Planning Data

Possible Future Classes:

- Emergency Data *(extremely important data)*
- Control Commands

1

Slide 62

1 Make sure we are okay with these numbers. No one did the math before on what this meant in terms of total points

Tim Yardley, 7/9/2011

Alarming and Notifications

- Bad data quality
- Security exceptions
  - E.g., Integrity failures, connection failures, access control
- Attestation failures
- Configuration changes
- System health

Who "touches" a SIEGate?

- The SIEGate application is like an ICCP node in a control center
- As a back-office tool, SIEGate is administered by specialists, and likely to become part of critical infrastructure
- For security and compliance, change is tightly managed

GSF Implementation

openHistorian

GRID PROTECTION ALLIANCE

What is a data historian?

- A non-relational database that is optimized for handling time-based process data
  - Data must be in the form of (time, value)
- Effectively handles very large volumes of data
- High performance read/write operations
- Easy migration of older data to less expensive, second tier storage media

Why install a historian?

- Relational systems are not a good fit for phasor data
  - Do not scale well (record overload & retrieval responsiveness)
  - Cost - higher storage consumption per point
  - Data backup processes can be problematic (outages and network congestion)
- Typical Historian uses in a Control Room Architecture
  - SCADA/EMS Data Storage
  - Primary Phasor Data Storage
  - Second Tier Phasor Data Storage

Who are historian vendors?

- GPA
- OSIsoft PI
- eDNA
- Honeywell Uniformance PHD
- GE Proficicy Historian
- Industrial SQL Server Historian

Who "touches" a data historian?

- A historian is like an enterprise-wide relational system (e.g., work management) that's just for operational, or process control, data. It requires diligent administration to enable enterprise-wide use
- A historian is used as the common point for systems to consume operational data in near-real-time; i.e., within about 1second of real-time
- Many engineers and analysts interact directly with a historian to obtain historical operating data

openHistorian 1.0 vs. 2.0

Version 1.0	Version 2.0

Version 1.0

- Two instances of the archiver are embedded in the openPDC and openPG
  - Data Historian
  - Performance Historian
- Configuration managed through openPDC or openPG Manager
- Includes two tools for data extraction/display
  - Data Extraction Tool
  - Data Trending Tool

Version 2.0

- Includes both archiver and server components
- Completely redesigned storage engine
  - Broader range of data types
  - Greater time precision
  - Improved storage efficiency
  - Improved performance
- Flexibility in implementation with integrated support for other open storage systems
- Includes an integrated suite of tools for data extraction and display

openHistorian 2.0 Design Goals

- **Complete redesign of current historian to enable the openHistorian to be the nexus for operational data at all sampling rates**
  - ACID protects data integrity
    Atomicity, Consistency, Isolation, Durability
  - High Performance
  - Maximum storage efficiency
  - High-availability
  - Compliant
  - Flexibility in deployment for rapid integration

Planned openHistorian 2.0 Components

- Archival Services
- Extraction Services and API
- Administrator's Console
- Web-based graphing/trending display
- Engineer’s Trending Tool and Screen Builder
- Operator’s Display
- Alarming / Notification Services

openHistorian 2.0 Features

- Optimized for management of process control and other time-series data
- Very large volumes of data can be efficiently stored and be made available on line
- Both lossless and swinging-gate compression options available
- Real-time data streams can be exported for both the provided web-based display or other application needs
- Horizontally scalable
- Easy to install, easy to configure
- Low cost of ownership
- Performance logging and alarming

openHistorian is ACID Compliant

- Atomicity - requires that database modifications must follow an "all or nothing" rule. Each transaction is said to be atomic
- Consistency - ensures that any transaction the database performs will take it from one consistent state to another
- Isolation - refers to the requirement that no transaction should be able to interfere with another transaction at all
- Durability - that once a transaction has been committed, it will remain so

ACID protects data integrity.

Who else uses the openHistorian?

- 1.0 Implementations:
  - TVA has been a long term user (since 1995)
  - Dominion
  - PG&E
  - Entergy
  - Anyone hosting an openPDC
- 2.0 Alpha Implementations:
  - OG&E