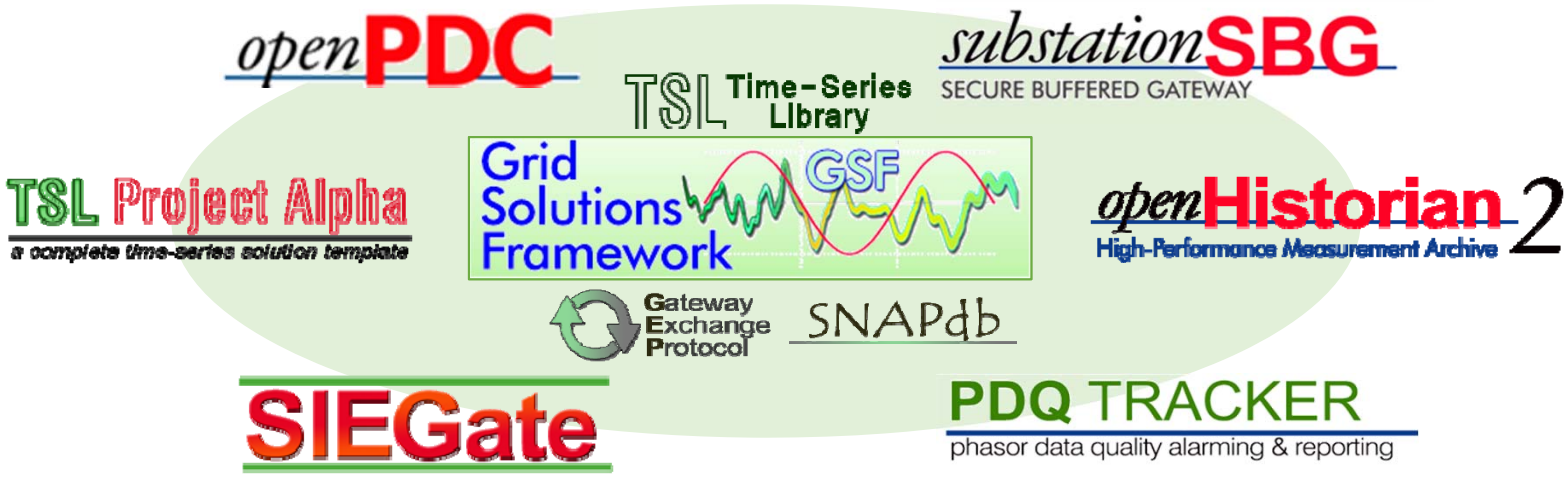
GRID PROTECTION ALLIANCE

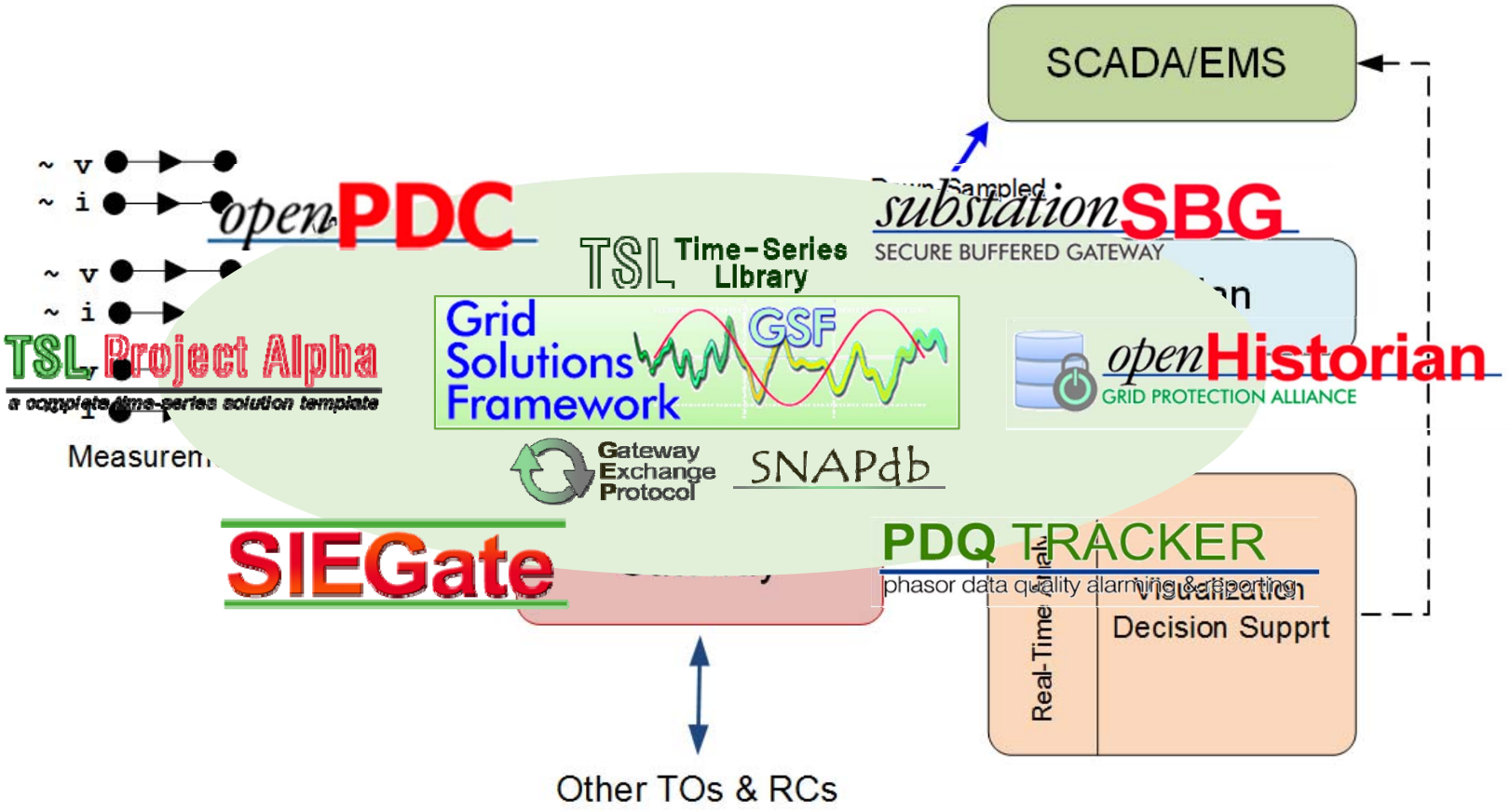
Synchrophasor Project Updates



GPA User's Forum 2015

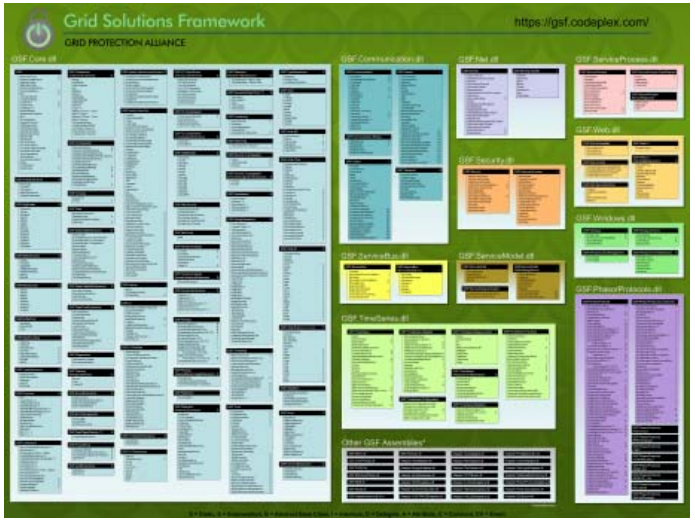
Atlanta, Georgia

Typical Synchrophasor Data Architecture



GSF

Grid Solutions Framework

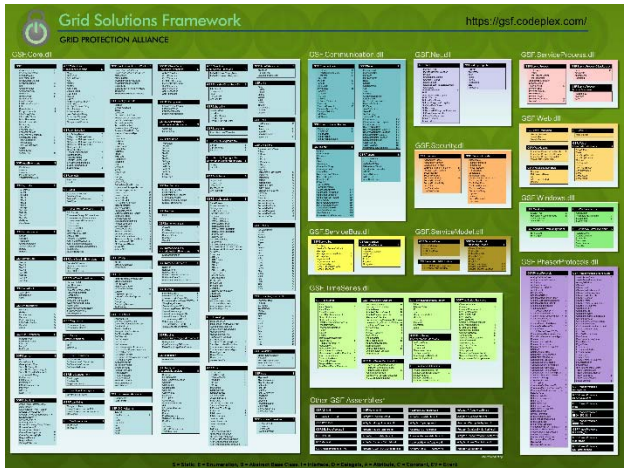


http://gsf.codeplex.com/

Grid Solutions Framework v2.1.90

- The Grid Solutions Framework (GSF) is a comprehensive collection of classes and methods useful for any .NET project.
- GSF is the foundational code library for **all** GPA products. It includes hundreds of class libraries that extend or expand the functionality included in the .NET Framework.
- GSF has around a half-million lines of actual code and 148,000 lines of comments spanning more than 40 assemblies - reference the online documentation for complete class details:

  http://www.gridprotectionalliance.org/NightlyBuilds/GridSolutionsFramework/Help/



Download GSF from:

http://gsf.codeplex.com/

– or –

nuget

http://www.nuget.org/

GEP

Gateway Exchange Protocol

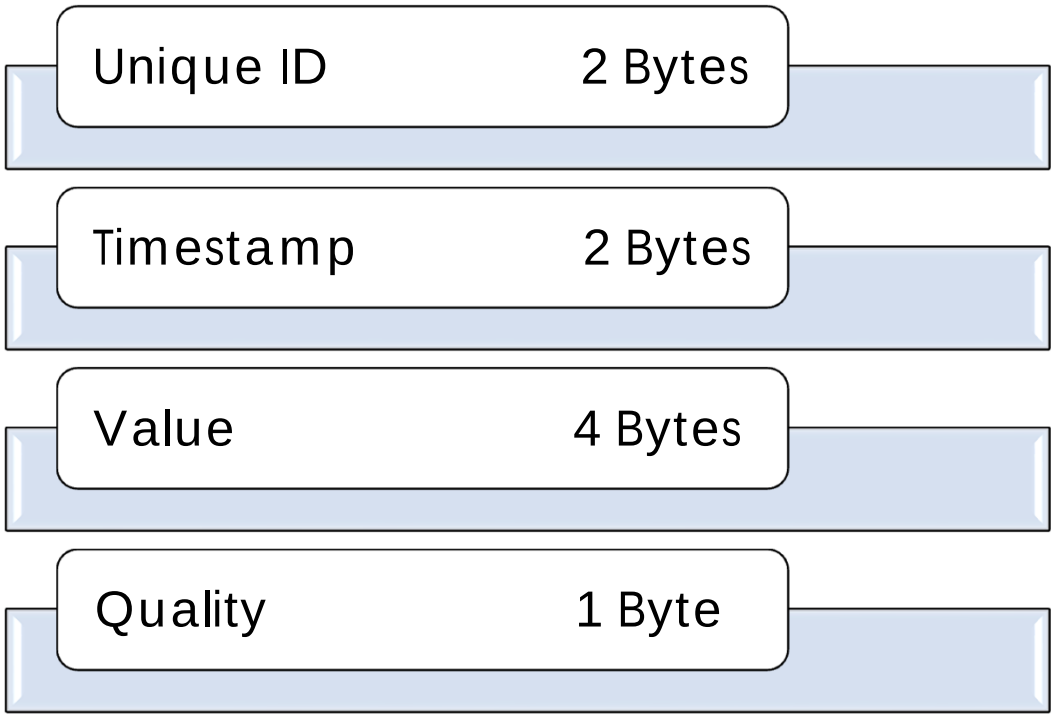
http://gsf.codeplex.com/

GEP Features

- Open and non-proprietary
- True pub/sub, measurement-based protocol
- Automated exchange of authorized metadata
- Tightly-compressed, binary serialization of time-series values
  - ID, time-stamp, value, flags
- Adapters provided in .NET, C/C++ and Java for convenient native integration in other systems
- Available transports include TLS, TCP, TCP with UDP, TLS with AES key-rotated UDP, or ZeroMQ
- Lossless compression is also supported.

Typical GEP Payload Structure*

Serialized Measurement Structure – 9 Bytes:



128-bit Guid ID mapped to 16-bit runtime ID

64-bit full resolution timestamp mapped to 16-bit offset

32-bit floating point value

8-bit quality flags

Several serialized measurements are grouped together to create a message payload. Total size is adjusted to reduce fragmentation.

* Free form payloads also supported.

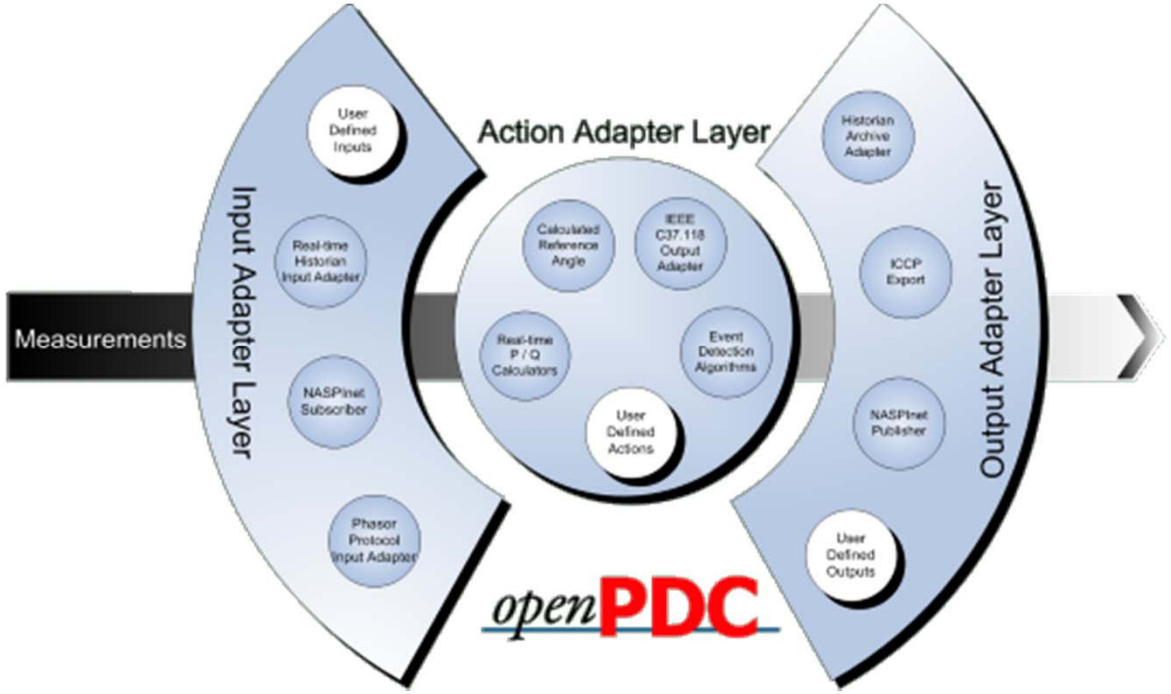
What's Coming for GEP

- Looking to bring technology to wider industry adoption through *standardization*
- New openECA development will bring architectural improvements to GEP by allowing new versions to accommodate robust data schemes, e.g., the Phasor Value Collection, through implementation of a generic key/value pair meta-data definition and transport

* Free form payloads also supported.

openPDC

Open Phasor Data Concentrator



http://openpdc.codeplex.com/

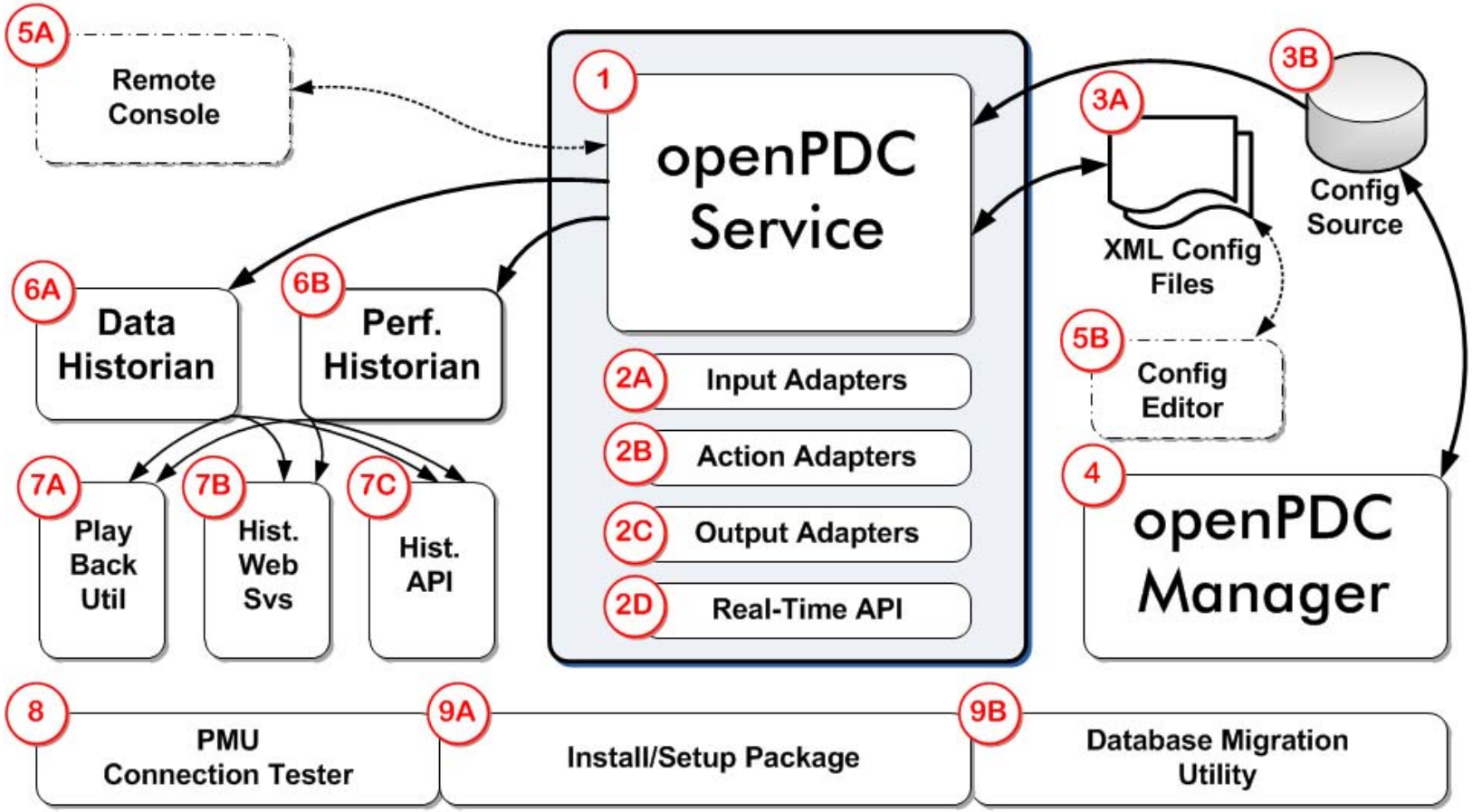
openPDC Features

- Supports all phasor input protocols
- Independently handles real-time and data archival functions
- Incorporates pre-emptive, time-aligned data publication
- Automated data availability reporting
- Can alarm on phasor magnitudes and/or angles
- All instances can be configured through an single application on an administrator's workstation

openPDC Features

- Future-proof adapter-based architecture
- Proven high-performance that scales with hardware
- Runs on multiple platforms and integrates with multiple configuration database types
- Includes a data and performance historian
- Output adapters included for the openHistorian, OSI-PI Historian and Hadoop
- The openPDC remains on a steep improvement curve

openPDC Components



Version 2.1 Improvements

- Automated data gap recovery
- Improved the “add new device” wizard
- Supports Linux / Apple OSX deployments
- Native OSI-PI adapter optimization with custom tag naming
- Plus more than 30 other enhancements and bug fixes

Released February 2015

Version 2.1 Service Pack 1

- Enhancements
  - Change of installer license to MIT
  - Support for GEP using ZeroMQ
  - Improved alarm configuration
  - DQ Report replaced by separate “data completeness” and “data correctness” reports
  - Improved configuration for data gap filling in clustered deployments

  … *as well as about 10 other significant enhancements*

Version 2.1 Service Pack 1

- Issue Resolution
  - Slow memory leak when leaving the openPDC Manager running and connected
  - OSI PI Adapter Fixes
  - Better memory management for GEP after periods of stress
  - TLS disconnection of unauthenticated clients

…. *and about 10 other major fixes.*

http://openpdc.codeplex.com/releases/

Planned openPDC Improvements

- Version 2.2 (March 2016)
  - openHistorian 2.0 Support
  - C37.118.2 Protocol Production Tested
  - UI Improvements (e.g., alarm configuration)

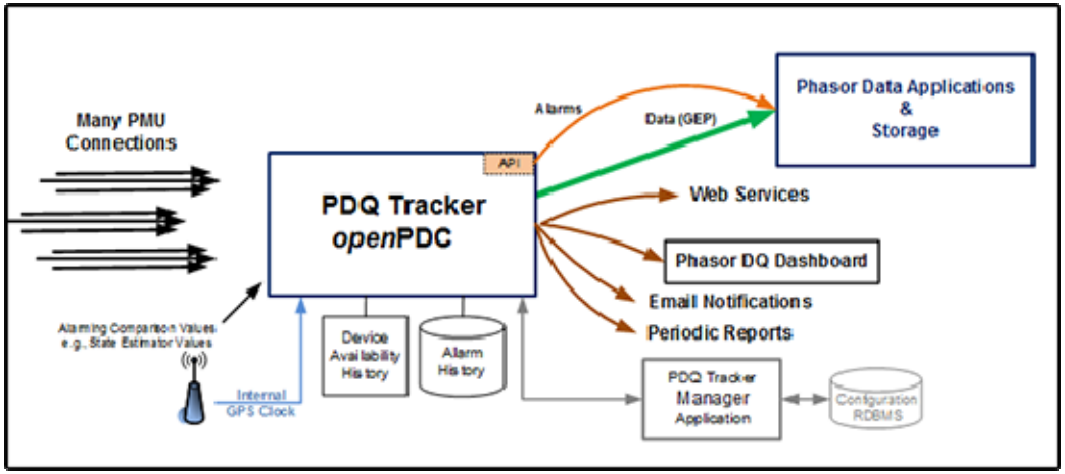
- Version 3.0 Release Candidate (Fall 2016)
  - Restructuring of TSL / synchronization engine
    - Routing and management of abstract objects
    - Support for the openECA analytics interface

PDQTracker

Phasor Data Quality Tracker

PDQ TRACKER

phasor data quality alarming & reporting



http://pdqtracker.codeplex.com/

Phasor Data Quality Needs Attention

- Data quality assurance is becoming increasingly important for successful integration of synchrophasor data into utility operations.
  - Device (PMU) availability
  - Time quality issues
  - Value quality issues
- Alarms are needed to alert real-time analytics and operators of bad or missing phasor data.
- Reports are needed to support businesses processes to improve data availability and data quality

Phasor Data Quality Tracker

- An open source project jointly funded by Dominion and PeakRC's new synchrophasor project
- Alpha Version now available which includes core functionality and two data quality reports
- Final beta version with increased functionality planned for release Spring 2015

PDQTracker Features

- Designed to raise alarms, track states, store statistics, and generate reports on both the availability and accuracy of streaming synchrophasor data.
- Will work with any vendor's PDC and synchrophasor data infrastructure
- Automatically produces periodic reports on phasor data completeness and correctness

High Level Features

- Focus is on the two major dimensions of quality
  - Data Completeness (Availability)
  - Data Correctness (Accuracy)
- Stand alone product for use within any synchrophasor data architecture
- Outputs to support:
  - Business processes for correcting / improving data quality
  - Integration with applications to flag incorrect data

Data Quality Tests

Completeness

- **Bad CRC**
- **Out-of-Order Frames**
- **Missing Frames**

Correctness

- **Time**
  - **Reasonableness**
  - **Latency**
- **Values**
  - **Reasonableness**
  - **Latched Value**
  - **Comparison Tolerance**

PDQ Tracker maintains statistics on data completeness

PDQ Tracker raises alarms to flag incorrect data

PDQTracker Example Report

PDQTracker Correctness Report

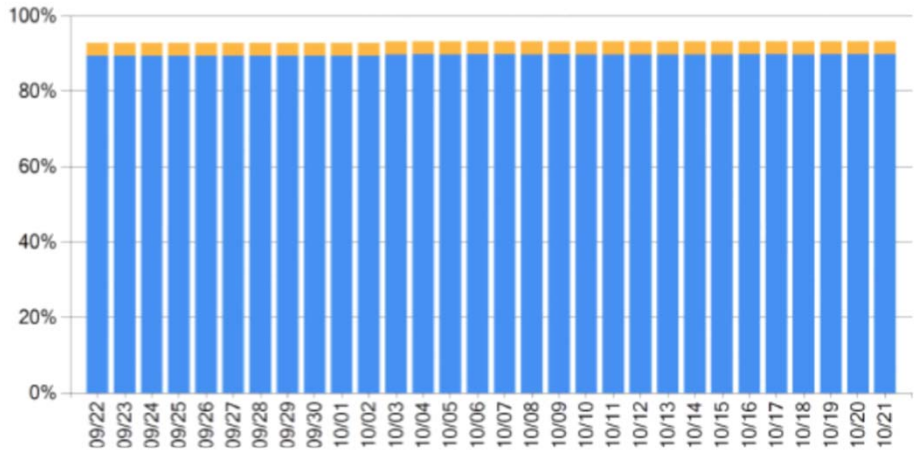
Grid Protection Alliance

Tuesday, October 21, 2014

5-day Correctness Summary

	10/17	10/18	10/19	10/20	10/21
Good	89.91%	89.88%	89.90%	89.89%	89.90%
Latched	1.84%	1.84%	1.84%	1.84%	1.83%
Unreasonable	1.57%	1.57%	1.57%	1.57%	1.57%

30-day Correctness Overview

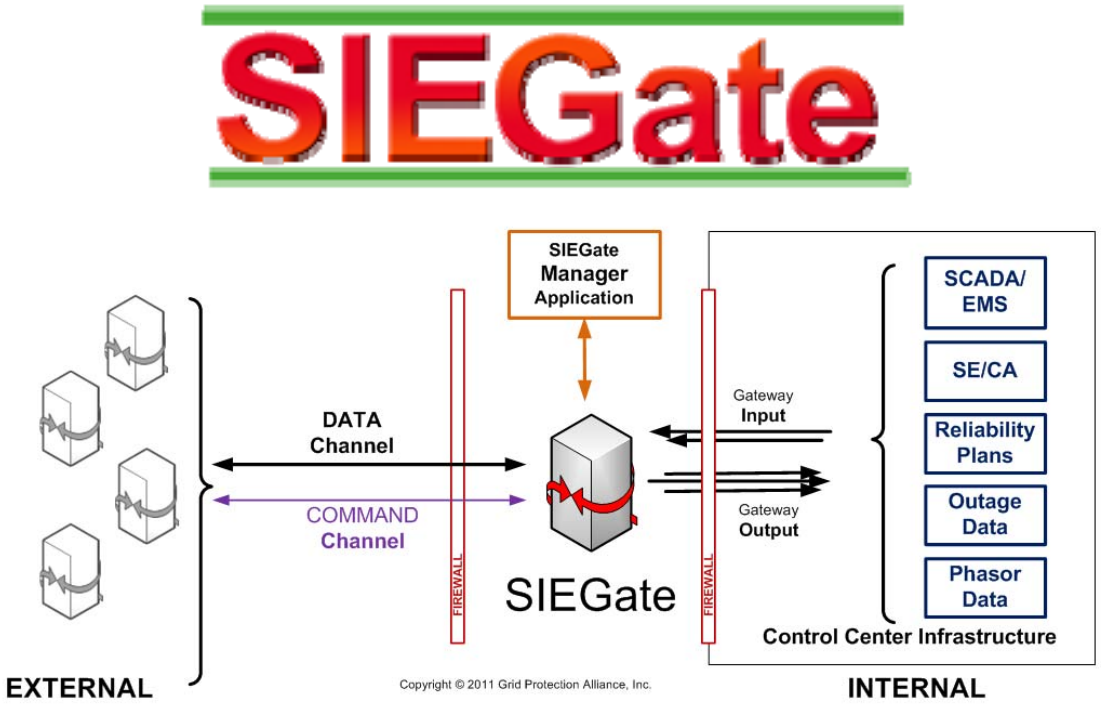


Beta Version Available

http://www.PDQTracker.com/

SIEGate

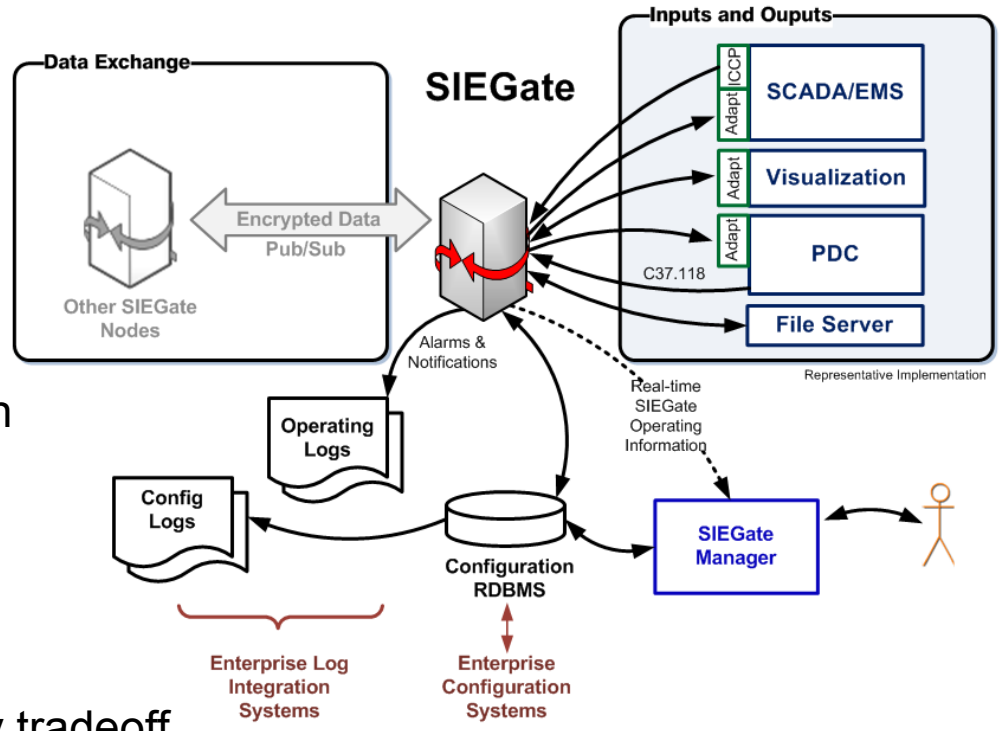
Secure Information Exchange Gateway



http://siegate.codeplex.com/

Technical Design Challenges

- Performance given system complexity
  - Support multiple data types efficiently and securely
  - Support multiple priorities
  - Minimize latency and maximize throughput
- High availability assurance
  - Horizontal and vertical scalability
  - SIEGate stability and reliability
  - Graceful performance degradation
- Security assurance
  - Maximize security performance
  - Minimize security breach impact
  - Configurable security levels
  - Security versus simplicity/usability tradeoff



SIEGate Protocol Requirements

- Highly Performant
  - Really fast
  - Really efficient

The Solution:

- Scale to millions of points per second in a single stream
- Leverage common IP transmission unit size to reduce datagram fragmentation
- Non-fixed payload contents, i.e., points in one packet can be different than the next

SIEGate Implementation

- Security-centric appliance designed to reliably exchange the information necessary to support real-time control room operations. SIEGate can exchange measurement data (ID, time, value, quality), alarm and notification data as well as batch or file-based data.
- Based on pub/sub technology that exchanges data among devices (such as other SIEGate nodes) using GPA's Gateway Exchange Protocol.
- GEP avoids being encumbered by IEEE C37.118 frame size issues and limitations. Single instance on common hardware can exchange around five million measurements points per second.

SIEGate v1.1 Release

http://siegate.codeplex.com/releases/

- Usability enhancements
- Updates and fixes included with service pack 1 of the openPDC
- Bug fixes since 1.0 version
- Includes “No Internet Fix Utility” to speed TLS connections when no Internet connection is available (common for SIEGate deployments)

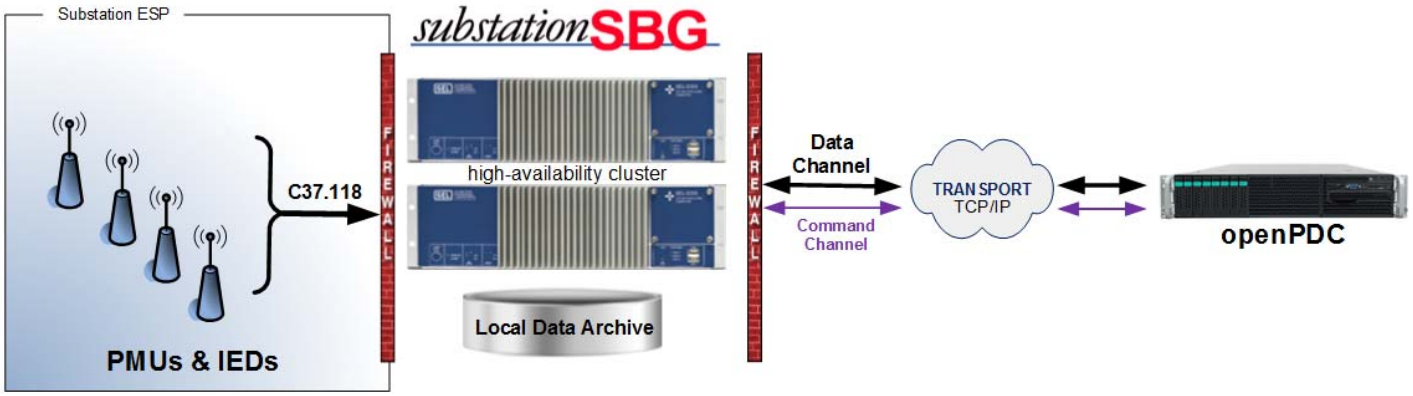
Deployments In Progress

- Southern Company
- Entergy
- OG&E
- MISO
- Dominion
- Duke
- PeakRC (2016 for testing and validation)

substationSBG

Substation Secure Buffered Gateway

substationSBG
SECURE BUFFERED GATEWAY



http://substationsbg.codeplex.com/

Feature Set at Conception

- Many local inputs
- Ability to capture DQ stats at the substation level
- Configuration optimized for substation use
- Automated GAP filling
- The security of SIEGate

Envisioned features have been implemented and deployed

FEATURES

Inputs

Comprehensive phasor input protocol support including IEEE C37.118, IEEE 1344, IEC 61850-90, Macrodyne, SEL Fast Message and F-Net protocols. A growing library of other substation protocols is supported including DNP3.

Security

The *substation*SBG can be configured so that gateway-to-gateway communications can be initiated only from the higher security zone (typically the control center) and it is designed for deployment on dual-NIC'ed hardware so that it can be a boundary appliance to form an ESP.

All communications between gateways is encrypted using industry -best Transport Layer Security.

Data Quality Monitoring

Performance statistics are logged every 10 seconds and include latency, availability, data quality, and time errors as well statistics on gateway input and output streams. Data quality alarms can be embedded in real-time gateway output streams.

Fully Automated Gap Filling

All data that moves through the *substation*SBG is persisted locally in a short-term rolling archive. After a communications outage between the substation and control center, data archived locally during the outage can be transmitted (at lower priority than real-time data) back to the control central to ensure that the central archive-of-record is complete.

Local Data Re-Formatting

All input sources can be converted into multiple standard phasor outputs for use in the substation. Down-sampling is supported.

Setup and Configuration

Setup is optimized and simplified for use in highly proceduralized substation settings — including simplification of processes to establish secure connections.

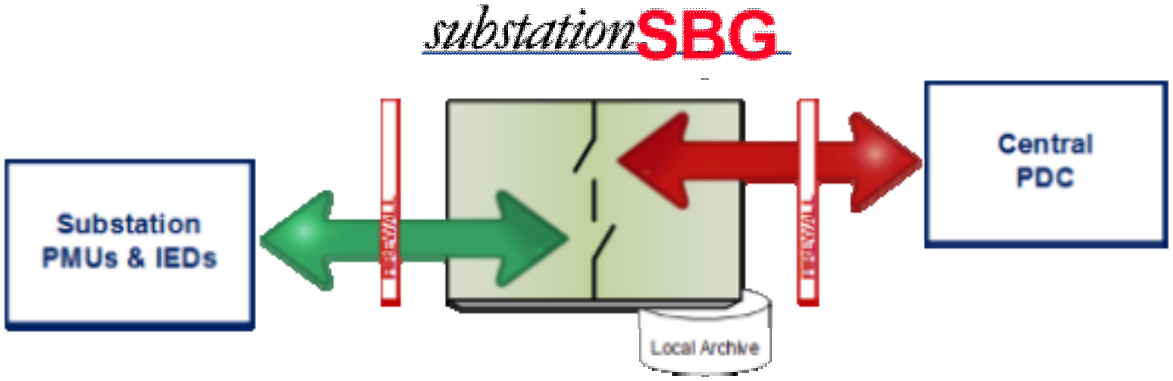
The *substation*SBG provides comprehensive logging services to improve security and meet regulatory compliance requirements.

Setup can be pre-configured and secured without the ability for local modification.

substationSBG Components

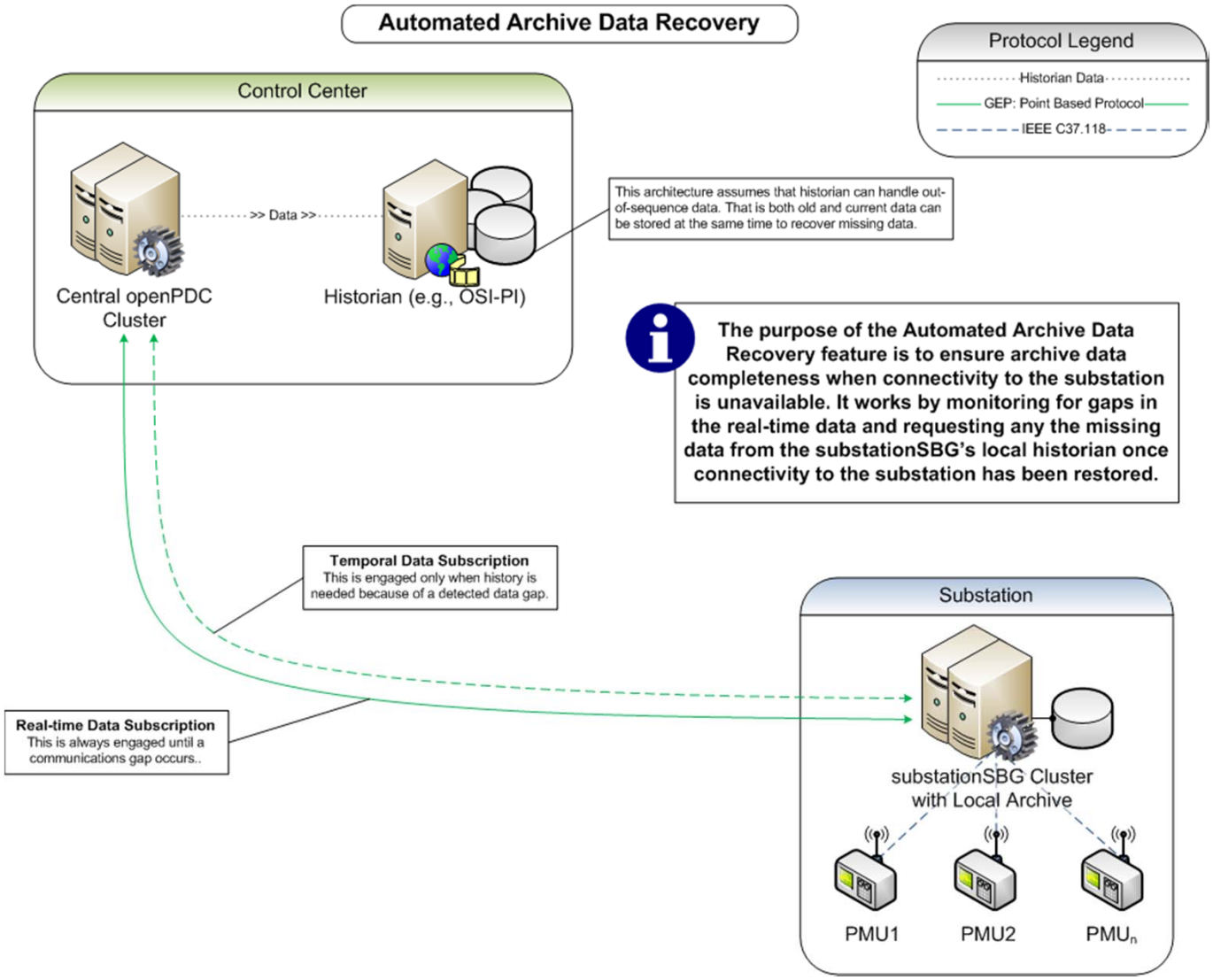
- Windows Core Service – Installed on each SEL 3355 with the cluster and runs automatically when the system starts – if service fails, will fail over to other machine
- Performance Historian – Installed on each SEL 3355 in the cluster and synchronized for statistics data generated by the substationSBG
- Phasor Data Historian – Installed on each SEL 3355 in the cluster and synchronized which becomes the local rolling buffer archive
- substationSBG Manager – GUI based management application installed locally on the SEL 3355
- Remote Console – Console based administrative diagnostics tool installed on the administrator's workstation – provides feedback from Windows Core Service

substationSBG Data Gap Recovery

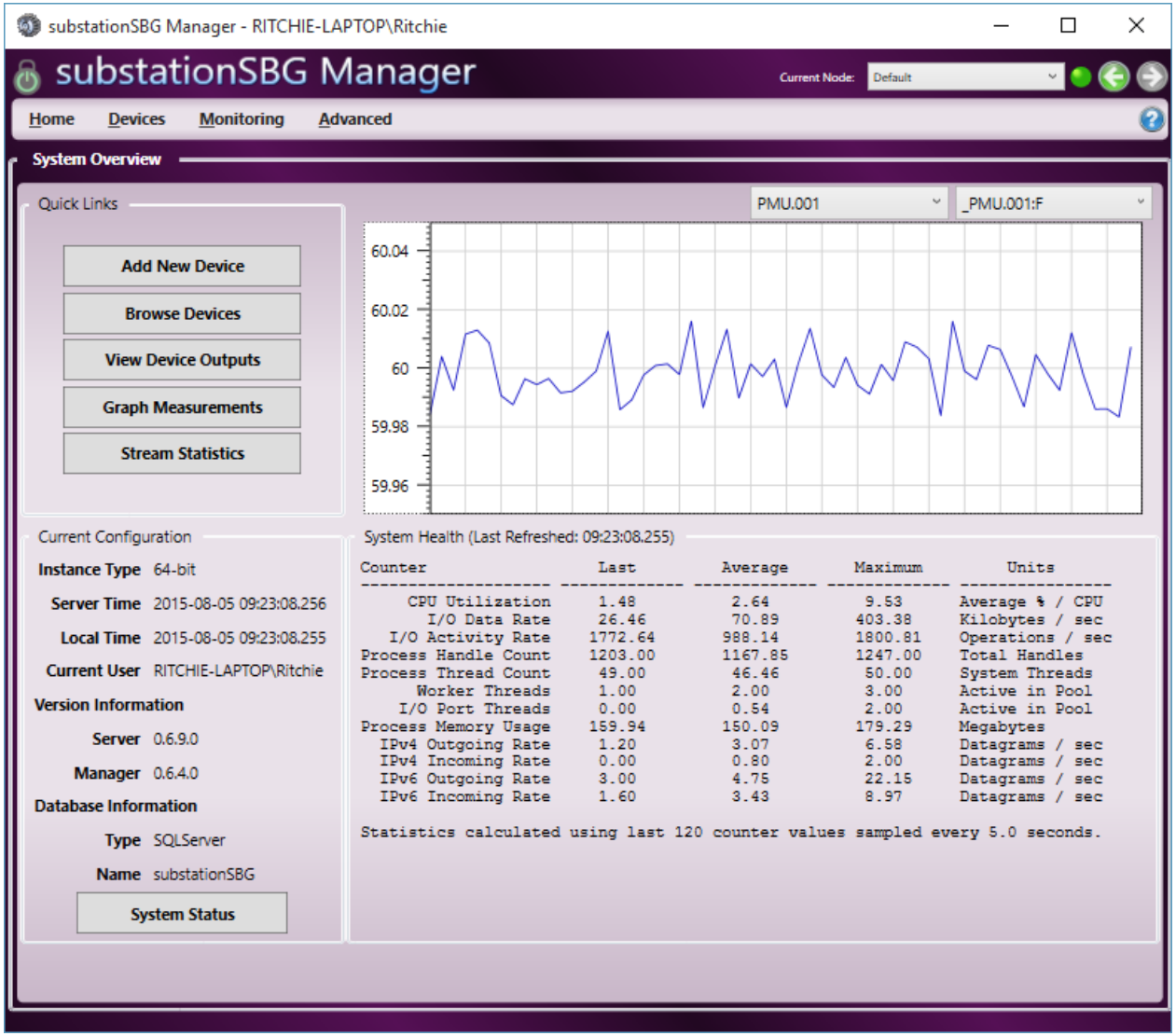


- The primary purpose of this feature is to recover data lost during communications interruptions:
  - The substationSBG archives data locally for a configurable period – the default is 45 days (not to exceed 80% of available hard drive size).
  - The central PDC keeps track of communications gaps (either from individual substationSBG's or from central PDC failure) and requests data from the substationSBG that is missing – and then pushes this data into the long-term archive.

substationSBG



substationSBG

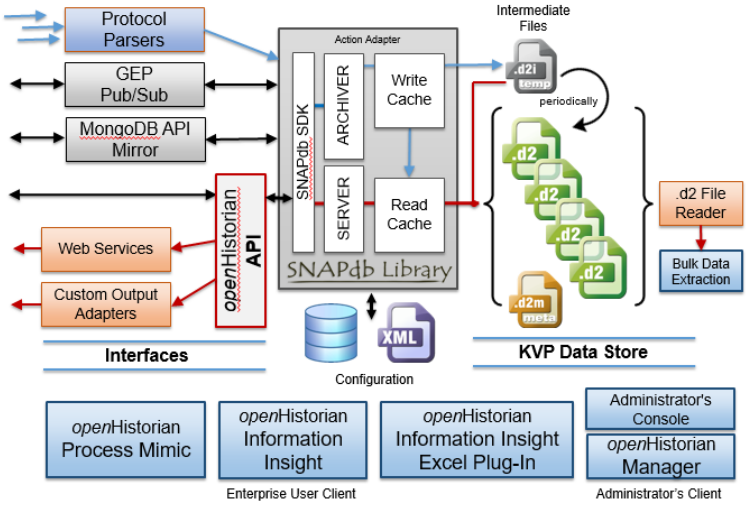


openHistorian

Open Source Time-series Data Historian

openHistorian 2

High-Performance Measurement Archive

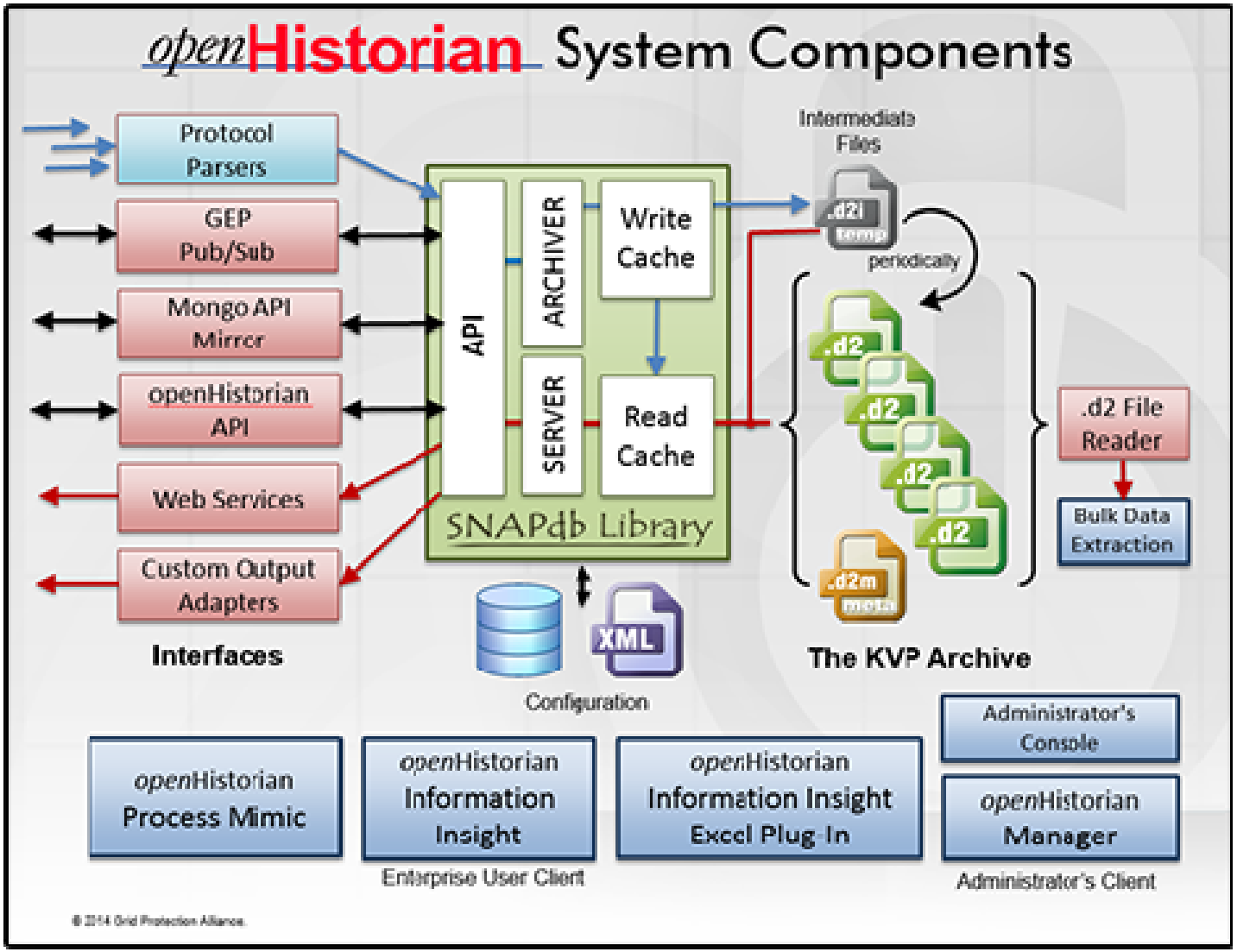


http://openhistorian.codeplex.com/

openHistorian

- The openHistorian 2.0 has been optimized for:
  - Assurance of archived data integrity / continuity
  - Broad data source connectivity
  - High performance data capture & retrieval
  - Efficient, high-volume data storage
  - High availability
- Early beta has been released which focuses on synchrophasor deployments

openHistorian



openHistorian Data Read API

```
// Example:
var enumerator = GetHistorianData("127.0.0.1", "PPA",
DateTime.UtcNow.AddMinutes(-1.0D), DateTime.UtcNow)

// API:
IEnumerable<HistorianMeasurement> GetHistorianData(
        string historianServer,
        string instanceName,
        DateTime startTime,
        DateTime stopTime,
        string measurementIDs = null)
```

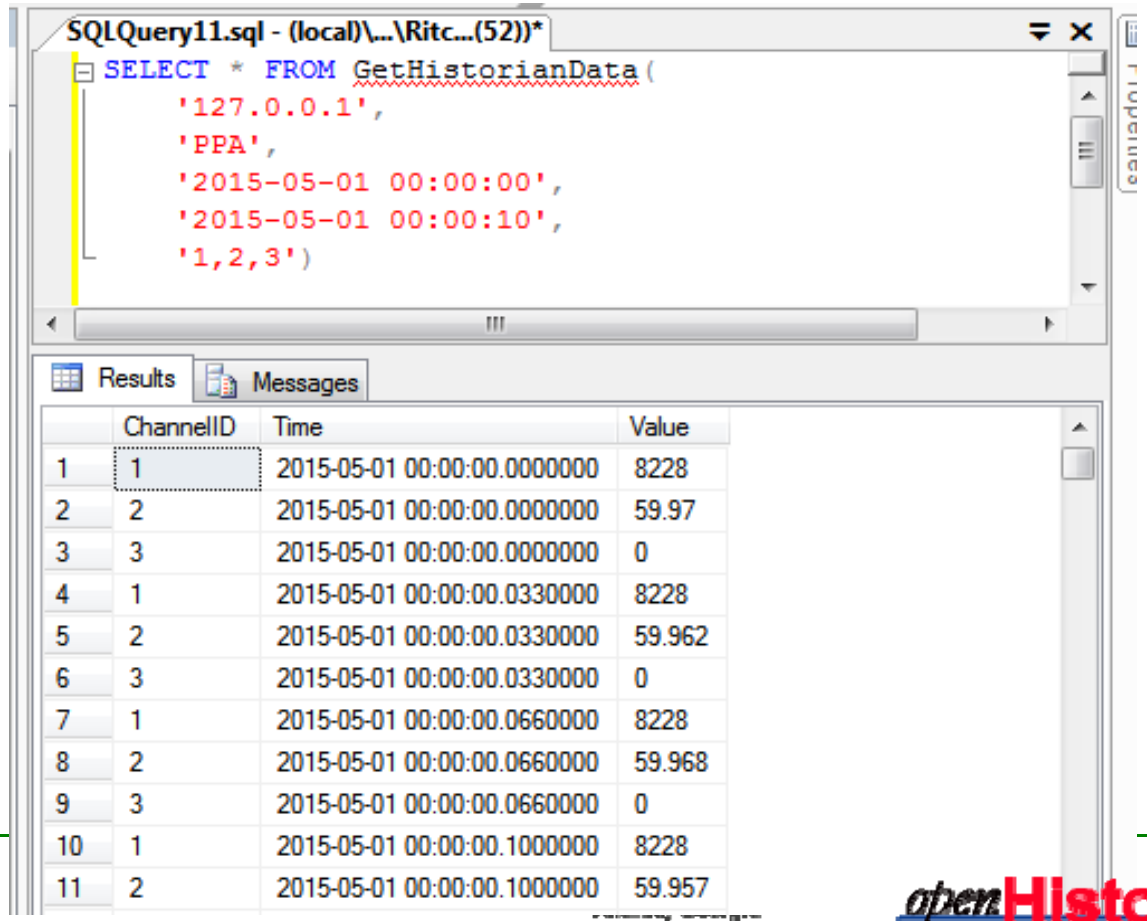
openHistorian Data Write API

```
// Example:
WriteHistorianData("127.0.0.1", "PPA", measurements)

// API:
void WriteHistorianData(
        string historianServer,
        string instanceName,
        IEnumerable<HistorianMeasurement> measurements)
```

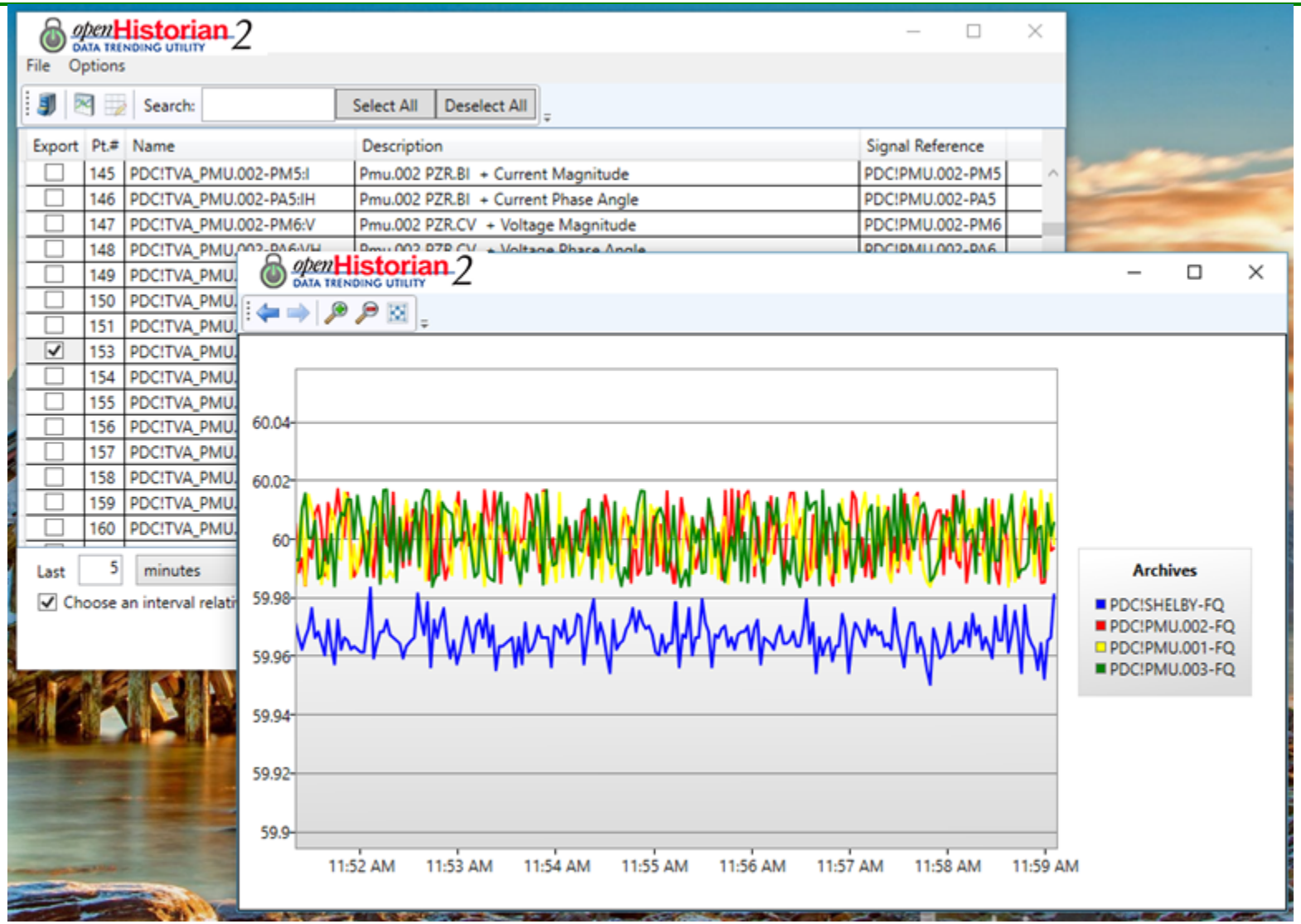
openHistorian SQL Server Integration

- Can query trending data from within SQL Server using SQL CLR adapter:

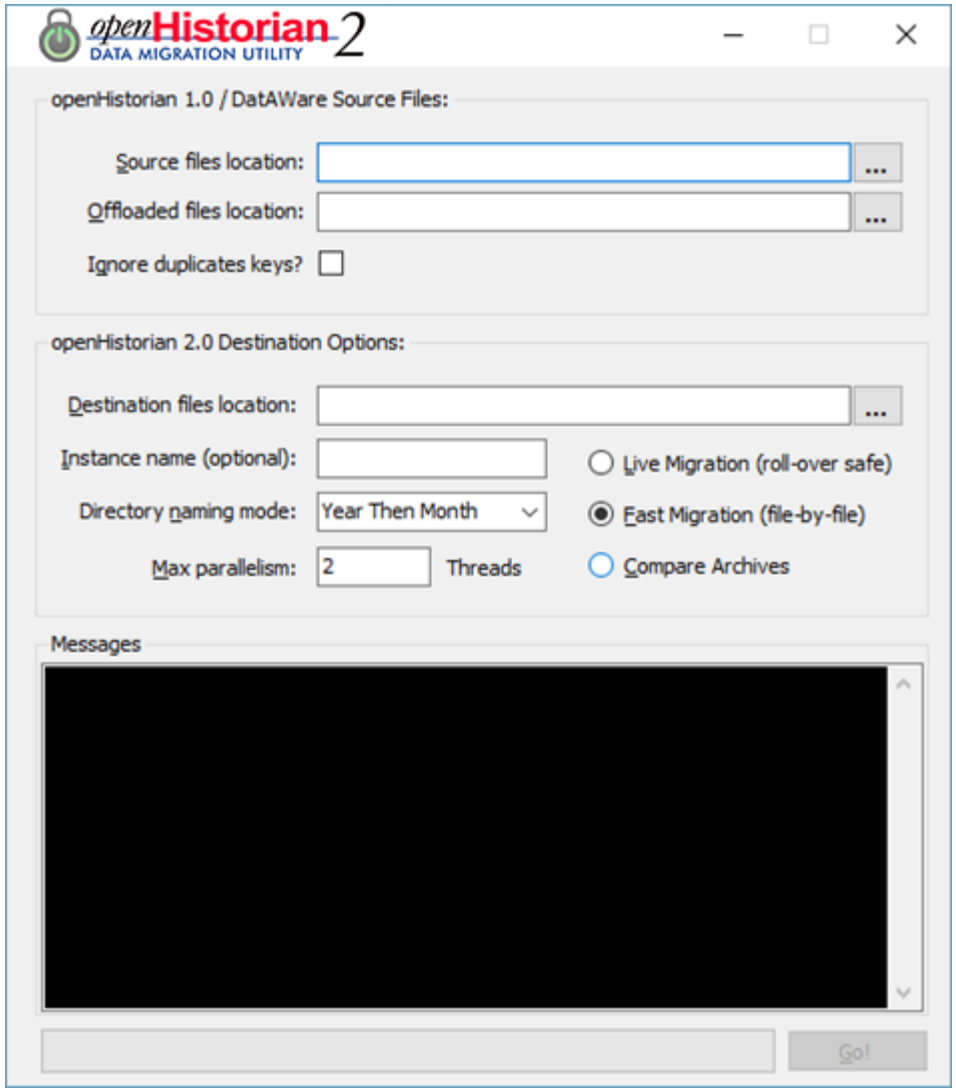


	ChannelID	Time	Value
1	1	2015-05-01 00:00:00.0000000	8228
2	2	2015-05-01 00:00:00.0000000	59.97
3	3	2015-05-01 00:00:00.0000000	0
4	1	2015-05-01 00:00:00.0330000	8228
5	2	2015-05-01 00:00:00.0330000	59.962
6	3	2015-05-01 00:00:00.0330000	0
7	1	2015-05-01 00:00:00.0660000	8228
8	2	2015-05-01 00:00:00.0660000	59.968
9	3	2015-05-01 00:00:00.0660000	0
10	1	2015-05-01 00:00:00.1000000	8228
11	2	2015-05-01 00:00:00.1000000	59.957

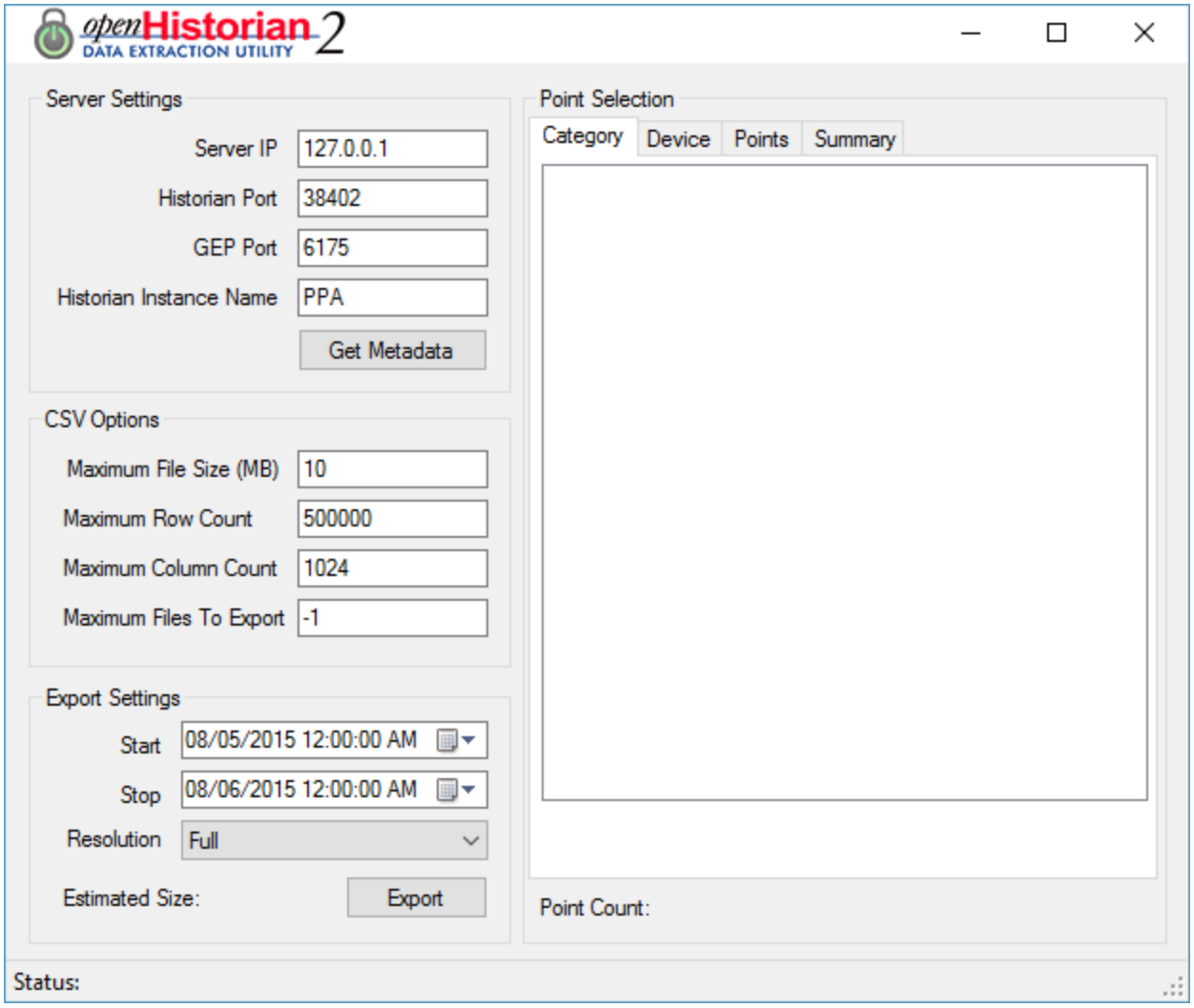
Data Trending Utility



Data Migration Utility (1.0 to 2.0)



Data Extraction Utility



Synchrophasor Visualization

http://www.gridprotectionalliance.org/Products/openHistorian/Media/Demos/