CAFIux: A NEW EPICS CHANNEL ARCHIVER SYSTEM

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Nov 14, 2018

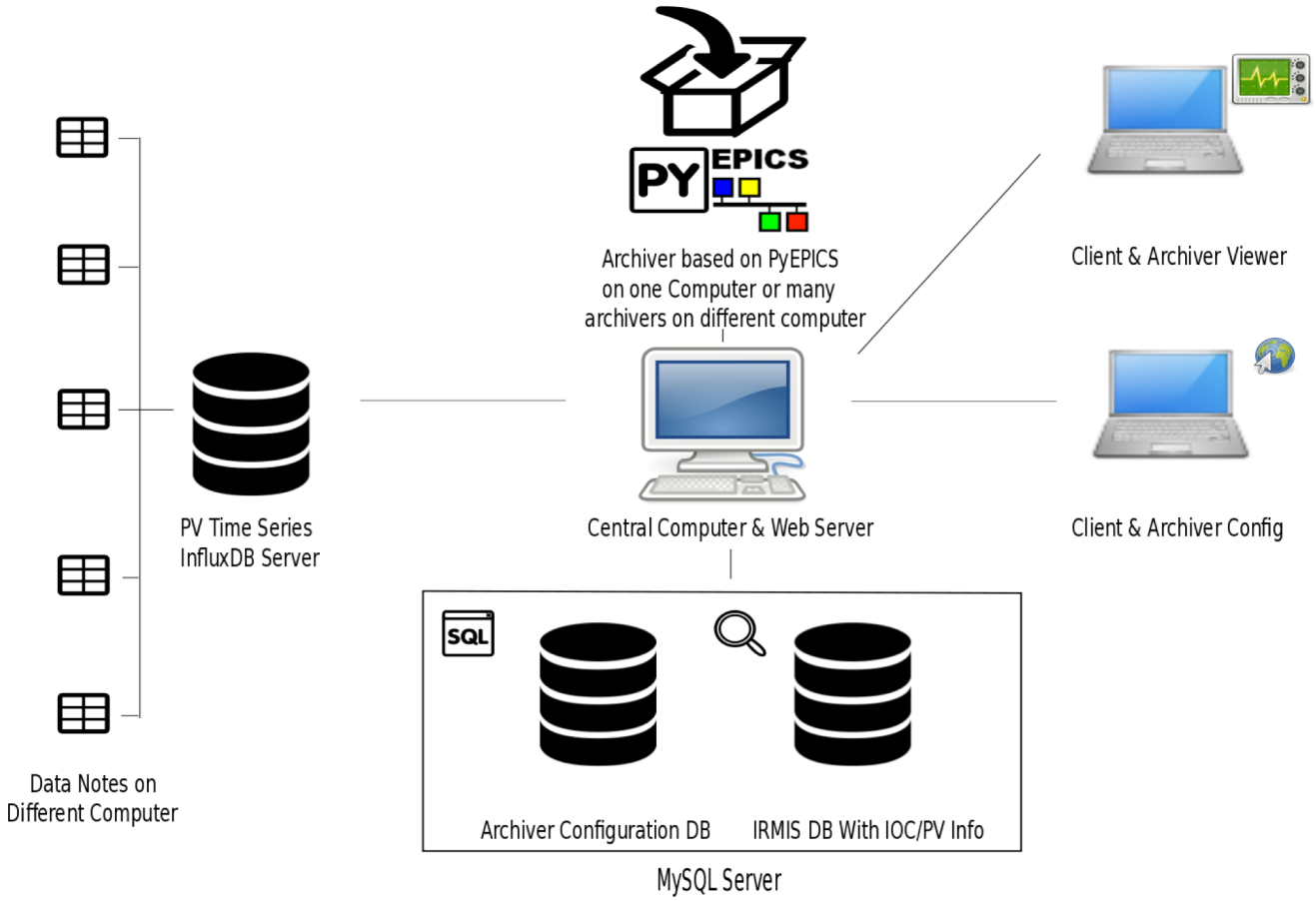
Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

CONTENTS

THE CURRENT LEGACY ARCHIVER SYSTEM AT LANSCE

- **Archiving storage and data collection**
  - Archive Engine – an EPICS channel access client
  - Archive Daemon to check archive engine status automatically
  - Several index files and large amount of data files
- **Data retrieval**
  - Java Archiver Client to browse data, to visualize data and to export data to spread sheets via a data server
  - A command line toolkits with functionality similar to the above Java client
  - Archive Data Server based on XML-RPC used to be a gateway for clients to access the data
- **Configuration**
  - Through XML configuration files
- **Released by SNS in 2006 and not an active project currently**
  - Unfortunately we do have an index file corrupted and have no idea how to fix it

A DIAGRAM OF CAFLUX AND RELATED SYSTEMS



INFLUXDB - A DATABASE SYSTEM OPTIMIZED FOR STORAGE AND RETRIEVAL OF TIME SERIES DATA IS USED AS CAFLUX STORAGE ENGINE

- **Fast READS and fast WRITES on high volume data**
- **Having a SQL like query language for RDBMS users**
- **Supporting a few hundred nodes initially and able to scale to a few thousand for future due to its clustering design**
  - Only one server node to be opened to archiving engines and application clients
- **Able to to create database, write and query data by using HTTP API**
- **But high performance on time series data at the expense of some functionalities**
  - Update functionality restricted
  - Delete functionality restricted
  - No cross table joins anymore
  - Fortunately the above functionalities rarely needed for our archiver system

INFLUXDB USED AS CAFLUX STORAGE ENGINE

- **Save our time and effort on developing a storage engine – different from legacy archiver**
- **Easy to use If you have some knowledge on SQL scripts**
  - An example for Python

```
from influxdb import InfluxDBClient
client =  InfluxDBClient(url, port, user, passwd, dbname, proxies=None)
client.write_points([ # to write two records
    {
        "measurement": "ioc",
        "tags"       : { "channel": "ABKS001" },
        "time"       : "2018-09-03 14:02:30",
        "fields"     : { "value": 0.22 }
    },
    {
        "measurement": "ioc",
        "tags"       : { "channel": "ABKS001" },
        "time"       : "2018-09-03 14:03:30",
        "fields"     : { "value": 0.25 }
    }
    ])

rs = client.query("SELECT * FROM ioc") # to red data
res = [(p["channel"], p["time"], p["value"]) for p in rs.get_points()] # get results
```

IMPLEMENTATION OF CAFlux DATA COLLECTION ENGINE – 2 TIERS

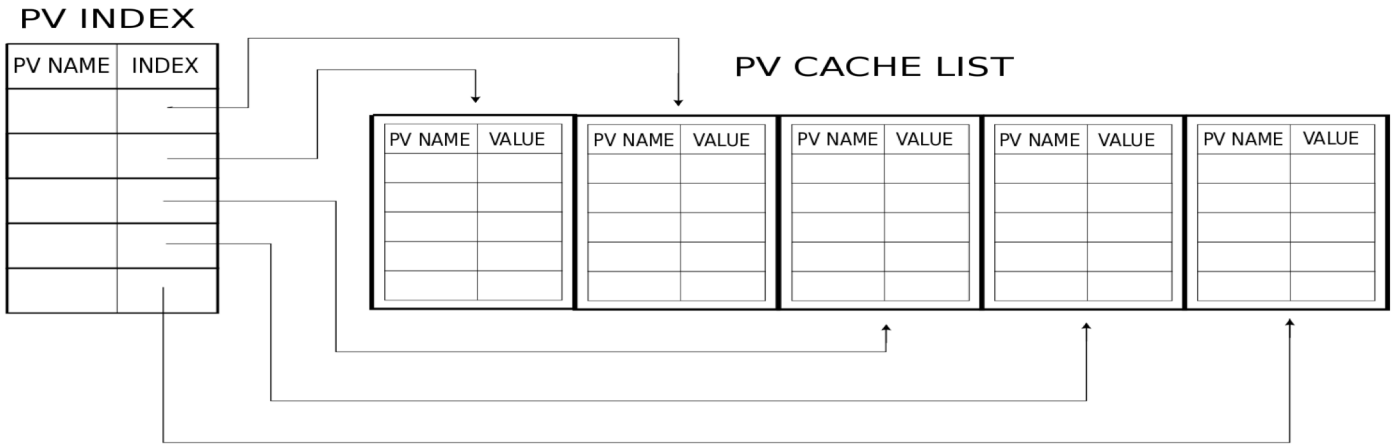
- **The 2-tier architecture for CAFlux data collection engine**
  - Lower level engine for core jobs - reading configurations, collecting and caching data, and saving data
  - Lower level engine designed as a daemon and developed with the Python asyncio and threads module
  - Upper level manager for monitoring the low level engine – checking the PID file, restarting the lower level daemon process if it is dead or in zombie status, logging error messages and sending emails if any issue happens
  - The upper level manager designed and implemented as simple as possible in order to make it more robust and stable enough for running 24 hours a day and 7 days a week with low probability for any issues

IMPLEMENTATION OF CAFlux DATA COLLECTION ENGINE – MULTITHREADING VS ASYNCHRONOUS

- **An obvious approach to use a timer thread for each PV to collect data, to save data and then to sleep for a presetting time and wait for the next cycle**
  - Large number of threads that do work a little time but sleep most of time
  - Limited by resources considering CA itself creating a lot threads when the PV volume is large
- **Another approach to start a thread to do work and then to let it die after**
  - Hard to develop and to manage threads
  - Needing a mechanism to start a thread at a presetting rate
  - Complicate to synchronize the action of multiple threads and to make sure that only one thread can access the shared resources
- **Asynchronous approach only to do all the work in the main thread**
  - One workhorse not enough to meet a large amount of work particularly when there are a large amount of PVs with high writing frequency

IMPLEMENTATION OF CAFlux DATA COLLECTION ENGINE – MULTITHREADING AND ASYNCHRONOUS COMBINATION

- **Global data containers synchronized for all threads**
  - A PV QUEUE for holding all PVs unhandled and disconnected due to an IOC down
  - A PV cache LIST keeping many thread-safe maps which contains a hundred pairs of PV names and PV values
  - A PV index DICT mapping PV name and the PV cache LIST index to search which map this PV belongs to



Note that PV Cache list contains many PVName-Val dicts and each dict shares the same thread locker.

IMPLEMENTATION OF CAFlux DATA COLLECTION ENGINE – MULTITHREADING AND ASYNCHRONOUS COMBINATION

- **The main thread**
  - To read inputs, initialize global data containers and start up
  - To initialize CA library and create CA context
  - To split new work threads
  - To include an asynchronous task to check and log the health status of each work thread at a period of few minutes and sleep in the rest of time
- **Each work thread**
  - Have a asynchronous task loop to handle hundreds of channels in a "parallel" manner
    - Scan the PV QUEUE and get a PV to work on it
    - Update a PVName-val map/dict contained in the PV cache LIST via the PV index DICT whenever a PV value changes
    - Get a PV value from the PV cache and write it to the storage
    - Set a lower priority for a channel if its status is found to be disconnected (probably due to its IOC down) and put it back to the PV QUEUE
    - Do the above steps again at the presetting rate

IMPLEMENTATION OF CAFlux DATA COLLECTION ENGINE – PV MONITORS BY PYEPICS MODULE

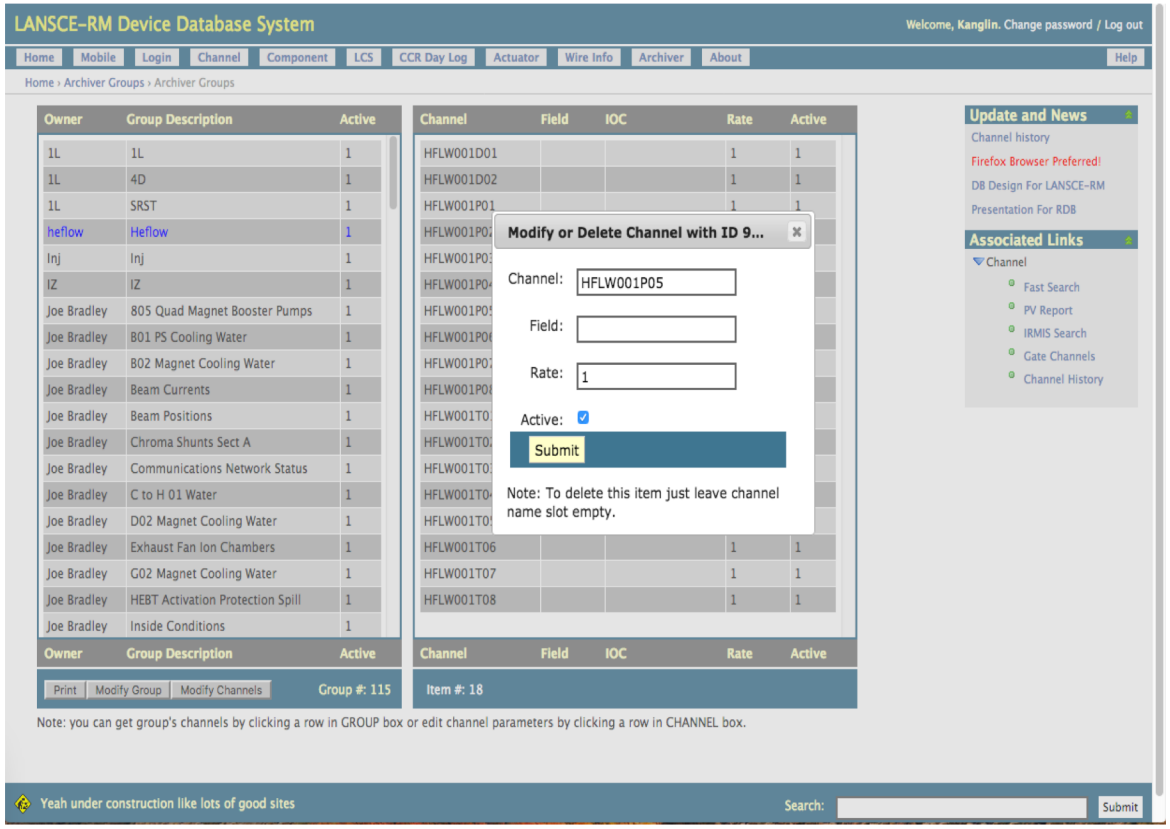
- **Creating a channel for every registered PV**
- **Subscribing a connection callback function to CA and called by CA whenever a channel connection status changes**
- **Subscribing a PV callback function to CA to monitor PV values and called by CA whenever PV value changes**
- **The PV central caches updated by the PV callback function to cache the "current" value on the channel collection server**
- **CA module of PyEPICS used to save our efforts and time to wrap the CA library and to make the implementation of the above steps easy**
- **Only trivial tweaks on the PyEPICS CA module for our multiple-threading needs, i.e. customizing PyEPICS CA module**
  - It might not be necessary if you really know how the PyEPICS CA module works and in this case you are completely dependent on Python GIL mechanism.
  - But those tweaks give us peace of mind(more details at Python workshop).

AN ONLINE CONFIGURATION SYSTEM – A 3-TIER WEB APPLICATION

- **A replacement of the legacy configuration files and a CGI web application**
- **Web browser as a platform for users to INSERT, READ, UPDATE and DELETE configuration information**
- **Web site developed with Python Django web framework**
  - Linux HTTPD ver 2.4 used for a web server
  - Apache mod_wsgi module to host the Python Django application
- **Configuration database built on a MySQL server**
  - Not on the same InfluxDB server for the data collection since UPDATE and DELETE functionalities needed for configuration but restricted on InfluxDB
  - The IRMIS system on the same MySQL server to provide detail information of archived PVs, e.g. their IOC information
- **A tool to load existing XML configuration files into the new system**

AN ONLINE CONFIGURATION SYSTEM – A 3-TIER WEB APPLICATION

- The frontend using JQuery AJAX and JQuery UI for a dynamic interface and web forms
- The backend implementing GET and POST methods to handle requests and send data
- The database consisting of a GROUP table and a CHAN table with 1:n relationship as shown



DATA RETRIEVAL AND VIEWERS

- **Data retrieval using SQL-like query language shipped with InfluxDB**
  - With help from the Python open-source InfluxdbClient module
  - Through a SELECT clause
- **Online archived data viewers**
  - Archived data streaming to view current data stored in real time
  - Archived data viewer for historical data stored
- **Viewer architecture and implementation - also 3-tier web applications**
  - Frontend developed with plotly.js - Javascript Graphing Library and JQuery AJAX
  - Backend developed with Python Django to query data and response to requests from web browsers
  - InfluxDB to manage data sources in addition to the data collection storage
- **Other free or commercial dashboards available for InfluxDB**
  - For example, Grafana shipped with data source plugin for InfluxDB

DATA RETRIEVAL AND VIEWERS – ARCHIVED DATA STREAMING TO VIEW CURRENT DATA STORED IN REAL TIME

DATA RETRIEVAL AND VIEWERS – ARCHIVED DATA VIEWER FOR HISTORICAL DATA

ARCHIVED DATA BACKUP AND RESTORE TO KEEP DATA IN SAFE AND CONSISTENT STATE

- **InfluxDB features for free (Not on the enterprise version)**
- **Data located at /var/lib/influxdb/data by default or somewhere you point to**
  - Time series data under the data directory
  - Meta data including user information, database and shard metadata, subscriptions, and etc. under the meta directory
- **Backup command line**
  - Run command “influxd backup –portable path-to-backup”
- **Restore command line**
  - Run command “influxd restore -portable path-to-backup”
- **Please refer to the manual at https://docs.influxdata.com/influxdb/v1.6 for details**

FUTURE WORK

- **Add data analysis and statistics like averages and standard deviations in the viewers**
  - With the help of the Python numpy and pandas modules
- **Monitor IOC status and adjust channels in a task loop accordingly**
  - Remove the channels of an IOC from a task loop if its status is OFF
  - Add the channels of an IOC into a task loop if its status if ON
- **Improve performance and availability with clustering nodes if really necessary**
  - InfluxDB OSS not support clustering
  - Clustering with InfluxDB Enterprise is not free
- **Develop data collection plugins for other database systems**