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Data streaming at SINQ

NOBUGS 2022 — New Opportunities for Better User Group Software

Until very recently standard data-acquisition electronics at neutron research facilities have saved data as a serie of bins in time and detector position (pixels): **histogramming mode**

Limiting factors

- Modest neutron flux
- Speed of acquisition electronics, network speed and disk space
- Lack of/outdated DAQ paradigms (histogramming)

During histogramming all **time information is lost**

New paradigm: **event-based** recording

For each neutron store

- pixel position
- timestamp

Each neutron can be correlated with state of instrument and sample environment (requires a data acquisition clock)

This enables **dynamic experiments**

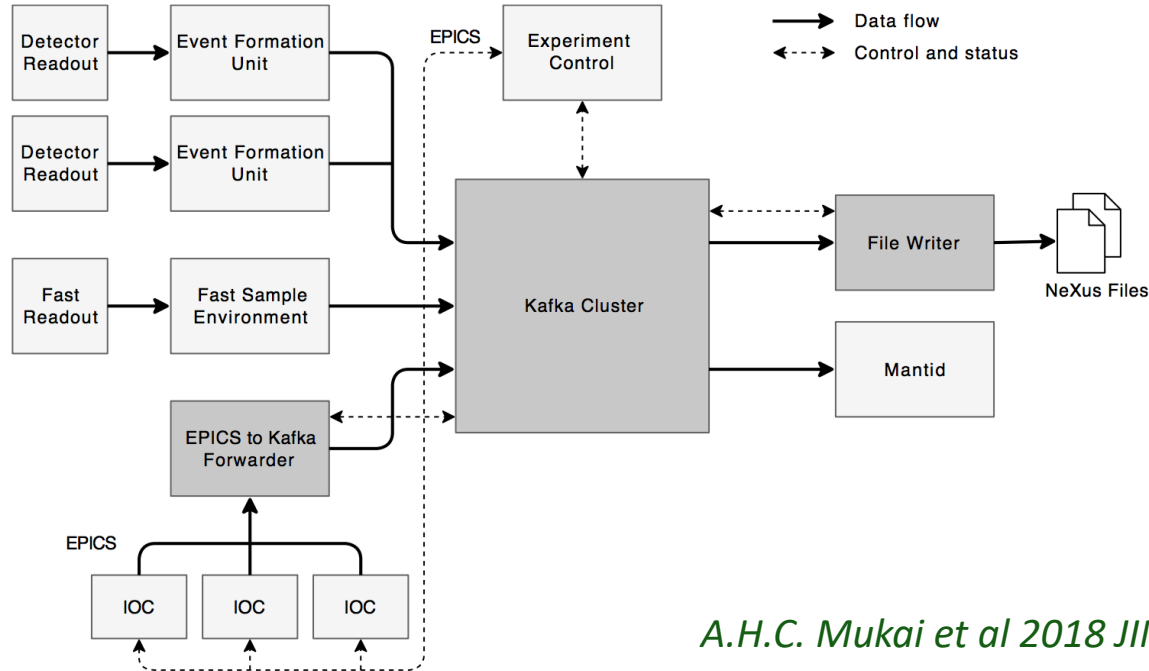
*“The BrightnESS programme is designed to ensure that **key challenges are met** in order to build an ESS that can deliver **high-impact scientific** and **technological** knowledge.”*

- WP 5: maximise the scientific output of the ESS by enabling **live** (real time) **processing** of the data taken on ESS instruments.
 - WP 5.3: develop the software to **aggregate** the sources of data into one data stream and make it available so that other software packages can use the data for processing.

Requirements:

- scalability
- reliability
- redundancy
- handling of clients and sources connecting and disconnecting

The outcome of BrightnESS has the following design



A.H.C. Mukai et al 2018 JINST 13 T10001

Kafka (<https://kafka.apache.org/>) is a pub-sub communication system. Key concepts:

- a stream of messages of a particular type is defined by a **topic**
- **producer** can publish messages to a topic
- the published messages are then stored at a set of servers called **brokers**
- **consumer** can subscribe to one or more topics from the brokers, and consume the subscribed messages by pulling data from the brokers.

These functionalities are “provided in a distributed, highly scalable, elastic, fault-tolerant, and secure manner”.

EPICS: set of software tools and applications which provide a software infrastructure for use in building distributed control systems to operate devices

(<https://epics-controls.org/>)

Google flatbuffers: cross platform serialisation library

(<https://github.com/google/flatbuffers>)

Mantid: framework that supports high-performance computing and visualisation of materials science data

(<https://www.mantidproject.org/>)

event-formation-unit: processing of neutron detector event data into neutron events and publish to Kafka

(<https://github.com/ess-dmsc/event-formation-unit>)

kafka-to-nexus: writes NeXus files from experiment data streamed through Kafka

(<https://github.com/ess-dmsc/kafka-to-nexus>)

forwarder: forwards EPICS PVs to Kafka

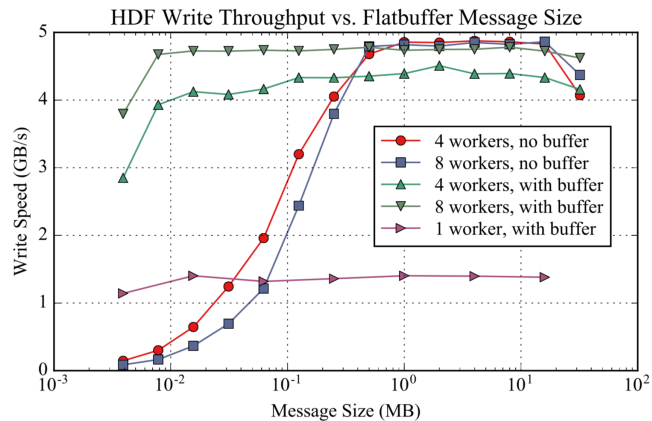
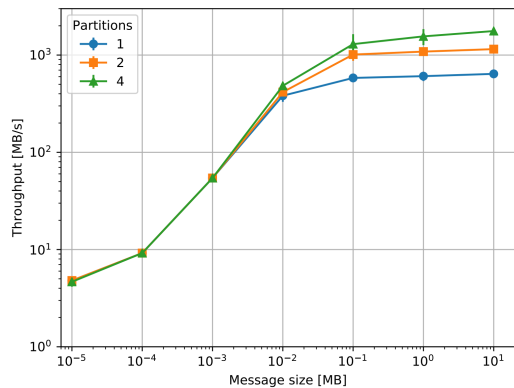
(<https://github.com/ess-dmsc/forwarder>)

just-bin-it: lightweight program for histogramming neutron event data

(<https://github.com/ess-dmsc/just-bin-it>)

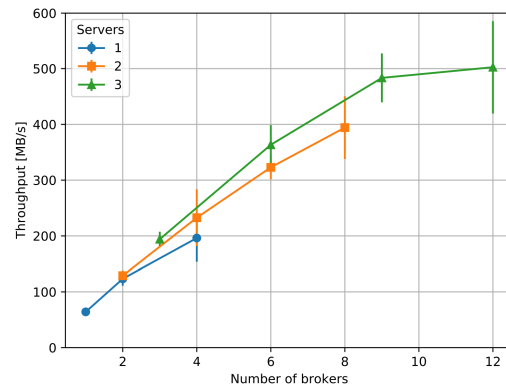
Tests performed on Intel Xeon E5-2690V4, 256 GB, GPFS via 4x Infiniband FDR

Producer Throughput vs Message Size



[D.Werder et al, JACoW-ICALEPCS2017-THPHA167]

Pipeline Throughput vs Number of brokers



Implementation at SINQ

Two instruments at SINQ are capable of event-stream: **AMOR** and **DMC**

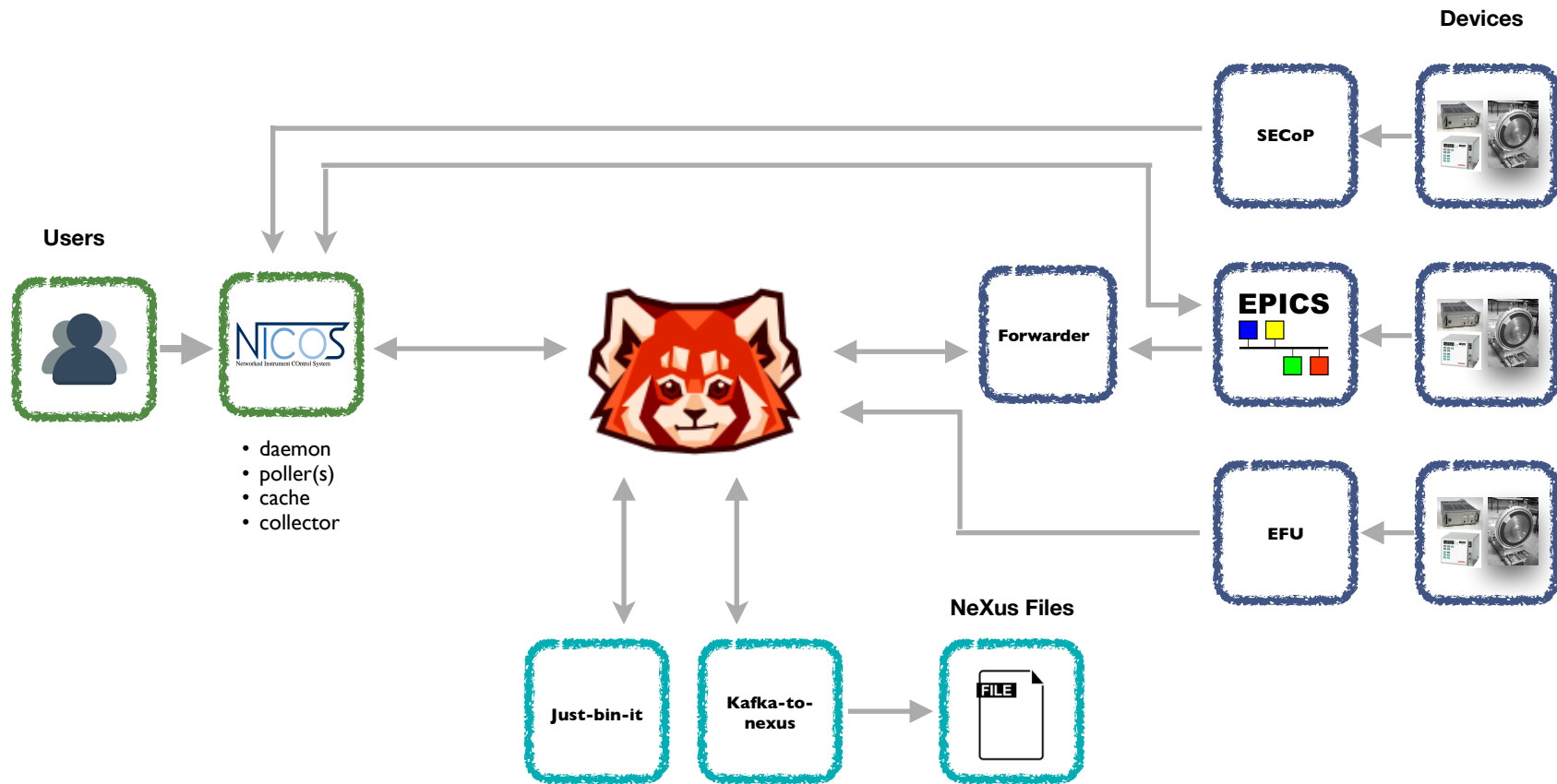
One (+ 1) instrument supports "2nd generation" detector electronics and is in principle compatible: **CAMEA** (+ **SANS-LLB**)

- **Redpanda** (<https://redpanda.com>) replaces Kafka (implements the Kafka API)
- there is no **global timing system**. We rely on NTP (PSI servers)
- sample environment uses **SECoP**, no direct connection to ~~Kafka~~ Redpanda

AMOR is **in production** since 2018 (currently stopped due to rebuilding)

DMC is **in production** since December 2021

Architecture at PSI



For a developer data looks like

```

..k/kafka-tools (-zsh)

=== 2022-08-08 07:25:55 ===
offset: 2899187
ev42
source: multiblade
message_id: 1184569
pulse_time: 1659936355000000000 (2022-08-08 07:25:55)
n_events: 2
pulse_time: [2641430768 1784080]
pulse_time: [10241 10241]

^C
Aborted!
(venv) ➔ kafka-tools git:(master) ✗ python kafka-spy.py -b ess01.psi.ch -t amor_detector -C -o begin | head -50

=== 2022-08-08 07:08:39 ===
offset: 2899138
ev42
source: multiblade
message_id: 1184520
pulse_time: 1659935319000000000 (2022-08-08 07:08:39)
n_events: 15
pulse_time: [2862441216 2862441264 2862441264 2862441408 2862441712] ... [871631248 871631344 871631344 871631632 871632996]
detector_id: [11169 11201 11137 11105 11233] ... [10817 10913 10881 10785 10945]

=== 2022-08-08 07:08:42 ===
offset: 2899139
ev42

..k/kafka-tools (-zsh)

=== 2022-09-12 07:24:00 ===
offset: 2441697
ev42
source: ttlmon0
message_id: 192160
pulse_time: 0 (1970-01-01 01:00:00)
n_events: 1
pulse_time: [92681264]
pulse_time: [1]

=== 2022-09-12 07:24:04 ===
offset: 2441698
ev42
source: ttlmon0
message_id: 192161
pulse_time: 0 (1970-01-01 01:00:00)
n_events: 1
pulse_time: [56626224]
pulse_time: [1]

=== 2022-09-12 07:24:05 ===
offset: 2441699
ev42
source: ttlmon0
message_id: 192162
pulse_time: 0 (1970-01-01 01:00:00)
n_events: 2
(venv) ➔ kafka-tools git:(master) ✗

..k/kafka-tools (-zsh)

(venv) ➔ kafka-tools git:(master) ✗ python kafka-spy.py -b ess01.psi.ch:9092 -t AMOR_filewriter -C

=== 2022-09-21 10:37:10 ===
offset: 10309055
x5f2
software_name: kafka-to-nexus
service_id: kafka-to-nexus:amor.psi.ch-pid:4625-a365
file being written: /home/amor/data/2022/commissioning/amor2022n000234.hdf
job_id: Z56a16ca-37f5-11ed-af61-6805caaa16f

=== 2022-09-21 10:37:12 ===
offset: 10309056
x5f2
software_name: kafka-to-nexus
service_id: kafka-to-nexus:amor.psi.ch-pid:4625-a365
file being written: /home/amor/data/2022/commissioning/amor2022n000234.hdf
job_id: Z56a16ca-37f5-11ed-af61-6805caaa16f

=== 2022-09-21 10:37:14 ===
offset: 10309057

..k/kafka-tools (-zsh)

(venv) ➔ kafka-tools git:(master) ✗ python kafka-spy.py -b ess01.psi.ch:9092 -t AMOR_nicosforwarder -C -o begin | head -20

=== 2022-09-08 01:01:53 ===
offset: 90146628
f142
source: se_r
timestamp: 1629406443860571392 (2021-08-19 22:54:03)
value: 1247.1

=== 2022-09-08 01:01:53 ===
offset: 90146629
f142
source: se_tt
timestamp: 163940263801567488 (2021-12-13 14:37:43)

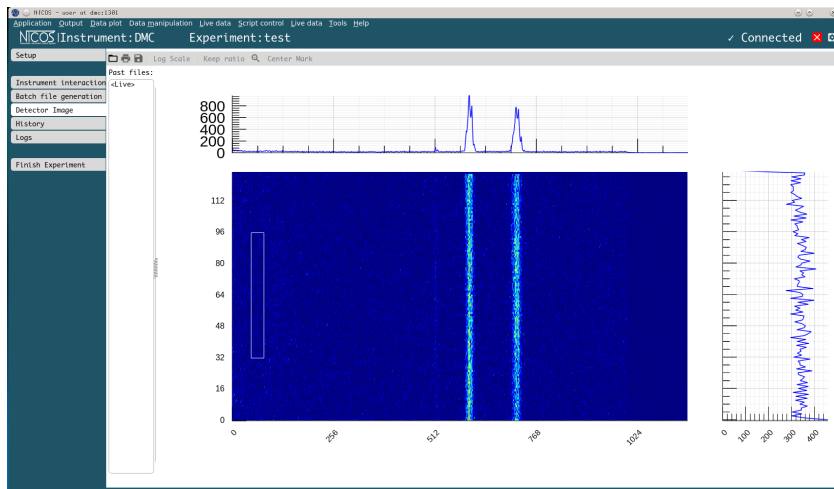
..k/kafka-tools (-zsh)

=== 2022-09-19 10:28:51 ===
offset: 489
{'cmd': 'config',
 'histograms': [{'data_brokers': ['ess01.psi.ch:9092'],
 'data_topics': ['amor_detector'],
 'det_range': [0, 11264],
 'height': 352,
 'id': 'nicos-det_image-1663576131',
 'left_edges': [],
 'num_bins': 50,
 'source': '',
 'to_f_range': [0, 100000000],
 'topic': 'AMOR_histograms',
 'type': 'hist2d',
 'width': 32}],
 'msg_id': 'nicos-det_image-1663576131',
 'start': 1663576131000}

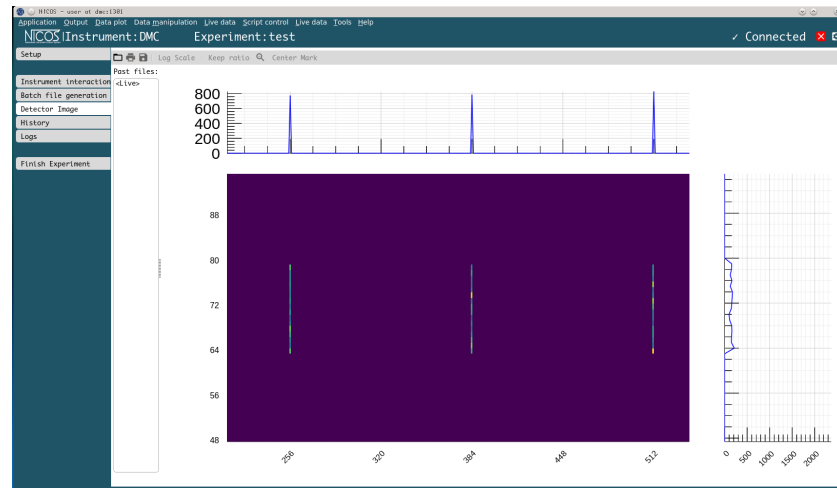
=== 2022-09-19 10:29:01 ===
offset: 490
{'cmd': 'stop',
 'msg_id': 'nicos-det_image-1663576131',
 'name': 'det_image',

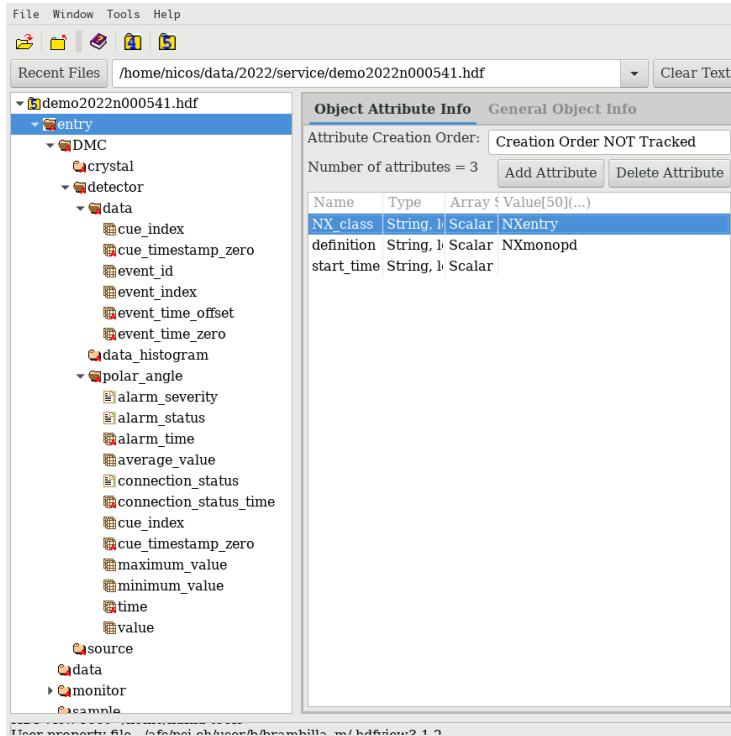
```

From the point of view of the user



Scattering patterns @ DMC





File Window Tools Help

Recent Files: /home/nicos/data/2022/service/demo2022n000541.hdf

demo2022n000541.hdf

- entry
 - DMC
 - crystal
 - detector
 - data
 - cue_index
 - cue_timestamp_zero
 - event_id
 - event_index
 - event_time_offset
 - event_time_zero
 - data_histogram
 - polar_angle
 - alarm_severity
 - alarm_status
 - alarm_time
 - average_value
 - connection_status
 - connection_status_time
 - cue_index
 - cue_timestamp_zero
 - maximum_value
 - minimum_value
 - time
 - value
 - source
 - data
 - monitor
 - example

Object Attribute Info General Object Info

Attribute Creation Order: Creation Order NOT Tracked

Number of attributes = 3

Name	Type	Array { Value[50](...)
NX_class	String, 1 Scalar	NXentry
definition	String, 1 Scalar	NXmonopd
start_time	String, 1 Scalar	

Table Import/Export Data Data

0-based

0	10849
1	10241
2	10241
3	2081
4	3905
5	3937
6	3873
7	2817
8	2785
9	2849
10	2753
11	2881
12	2552

Table Import/Export Data Data Display

0-based

0, = 1663222992000000000

0	1663222992000000000
1	1663222998000000000
2	1663223003000000000
3	1663223010000000000
4	1663223014000000000
5	1663223021000000000
6	1663223025000000000
7	1663223029000000000
8	1663223033000000000
9	1663223046000000000
10	1663223050000000000
11	1663223055000000000

Table Import/Export Data Data Display

0-based

2, = 119324528

0	59483136
1	76136176
2	119324528
3	13260320
4	77302096
5	77302448
6	77302496
7	17445824
8	17445872
9	17445888
10	17445968
11	17446064
12	17446880

- the “hit” position are recorded as 1-D pixel array
- the timestamp/ToF is reconstructed from a time_zero and a time_offset

Conclusion

As member of the BrighnESS collaboration PSI contributed to the design and implementation of a new paradigm for data acquisition and storage

Thanks to the SINQ upgrade program and new detectors we are able to store experimental data in the form of a data stream and store it to a NeXus file

To achieve a complete event-based experiment we still miss

- hardware for event-based sample environment
- a global time system to ensure synchronisation of timestamp with high resolution

