UT-BATTELLE

EPICS Channel Access Revisited

2006

kasemirk@ornl.gov

SNS
SPALLATION NEUTRON SOURCE

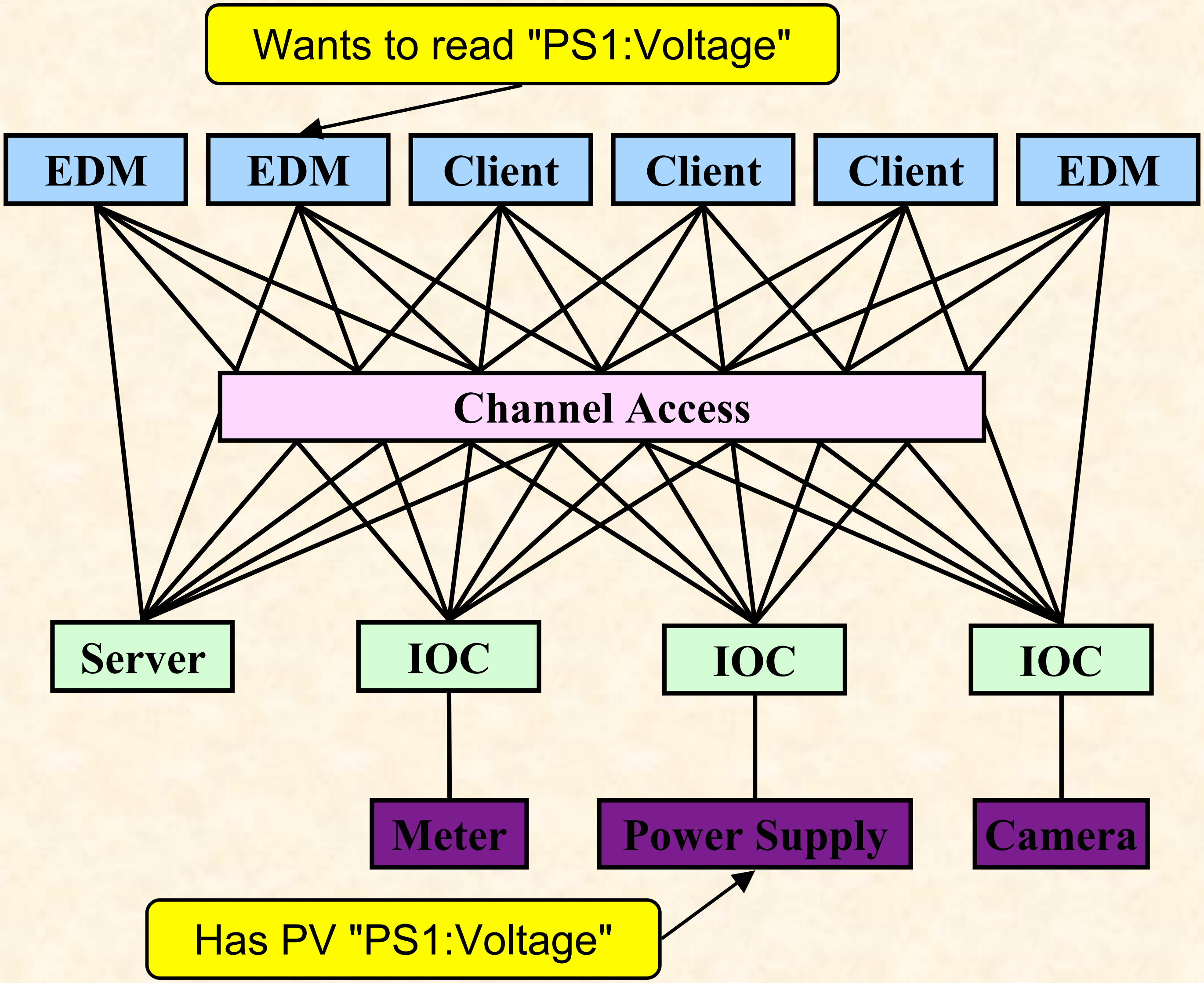
06-G00576/arm

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Channel Access

- What is a Channel (Process Variable)?
  - A field in a record. Except when there is no record!
- What are the properties of a PV?
  - Other fields of the record? Which ones?
    What if there is no record?
- How does CA "find" a channel on the network?
  - Why does it not find your PVs?
  - Why does it find them more than once?
- How are network interruptions handled?
  - Why does my client fail to reconnect?

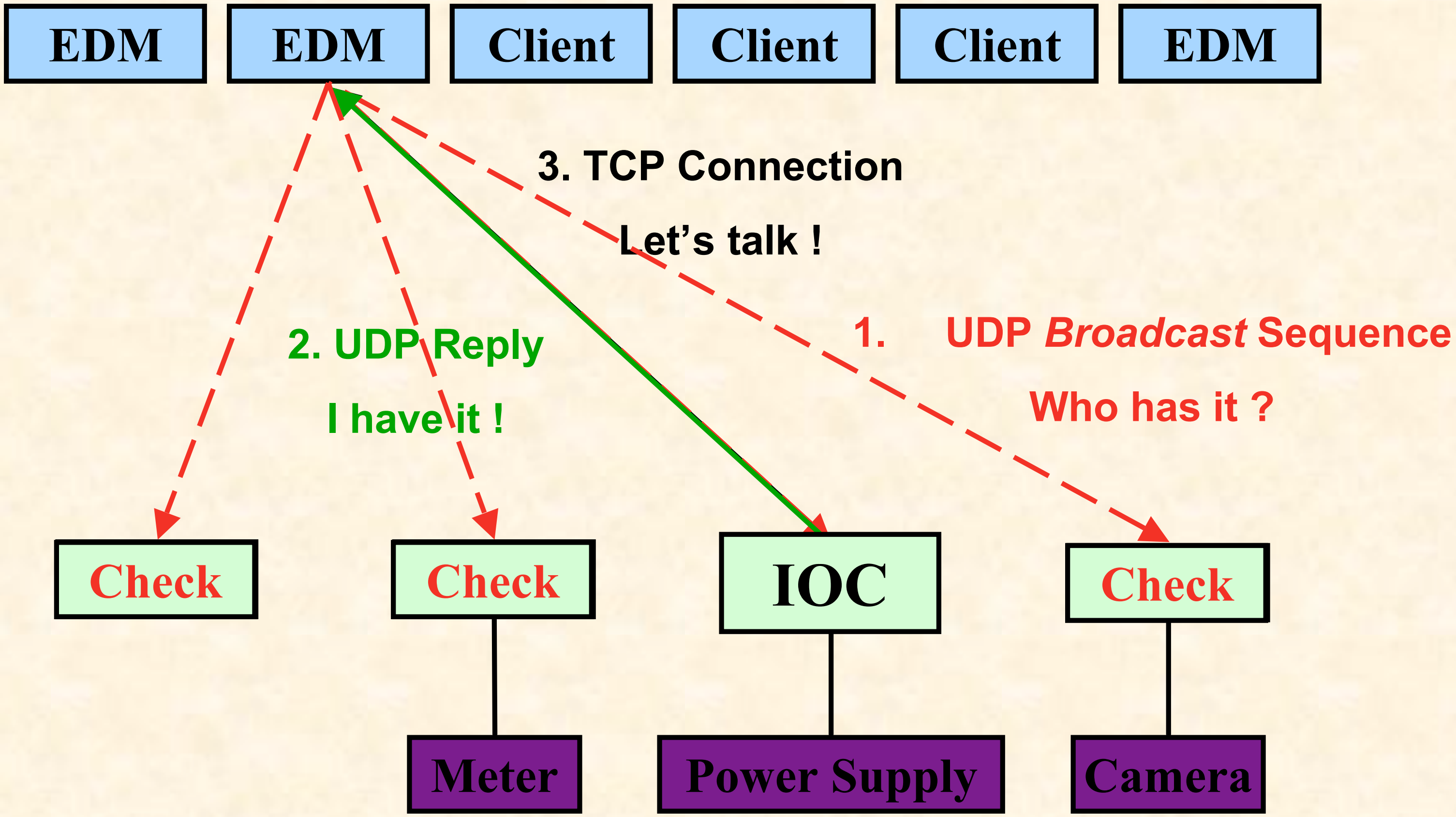
EPICS Overview



Internet 101

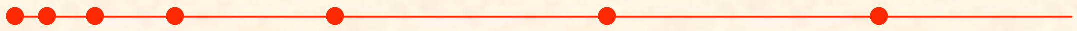
- The Internet Protocol (IP) consists of UDP and TCP
  - We ignore the very low-level Internet Control & Message Protocol (ICMP).
- User Datagram Protocol (UDP)
  - Sends a network packet
    - from one port on one computer
    - to one or more ports on one or more other computers.
  - Fast!
  - Checksum: If the packet arrives, it's OK.
  - But not reliable: Packets get lost, arrive out-of-order, arrive more than once.
- Transmission Control Protocol (TCP)
  - Sends a stream of bytes from one port on one computer to another port on another computer.
  - Reliable: Bytes arrive at the receiver in the correct order.
    - Basically adds serial numbers to UDP packets, requesting repeats for missing packages.
  - But slower, and message boundaries get lost:
    - "Hello Fred!" might arrive as "Hel" <pause> "lo F" <pause> "red!"

Search and Connect Procedure



Search Request

- A search request consists of a sequence of UDP packets
  - Per default: Broadcast to the local subnet.
    - Basically plug-and-play when you get started.
  - Or to IP addresses listed in EPICS_CA_ADDR_LIST
    - Routers do not forward broadcasts!
    - You have to add 'other' subnets or specific IOCs off the local subnet to that environment variable!
  - Starts with a small interval (30 ms)
    - Doubles each time, until reaching 5 second intervals.
    - Stops after 100 packets (~8 minutes) or when it gets a response
    - Wakes again on "beacon anomaly" (details follow later)

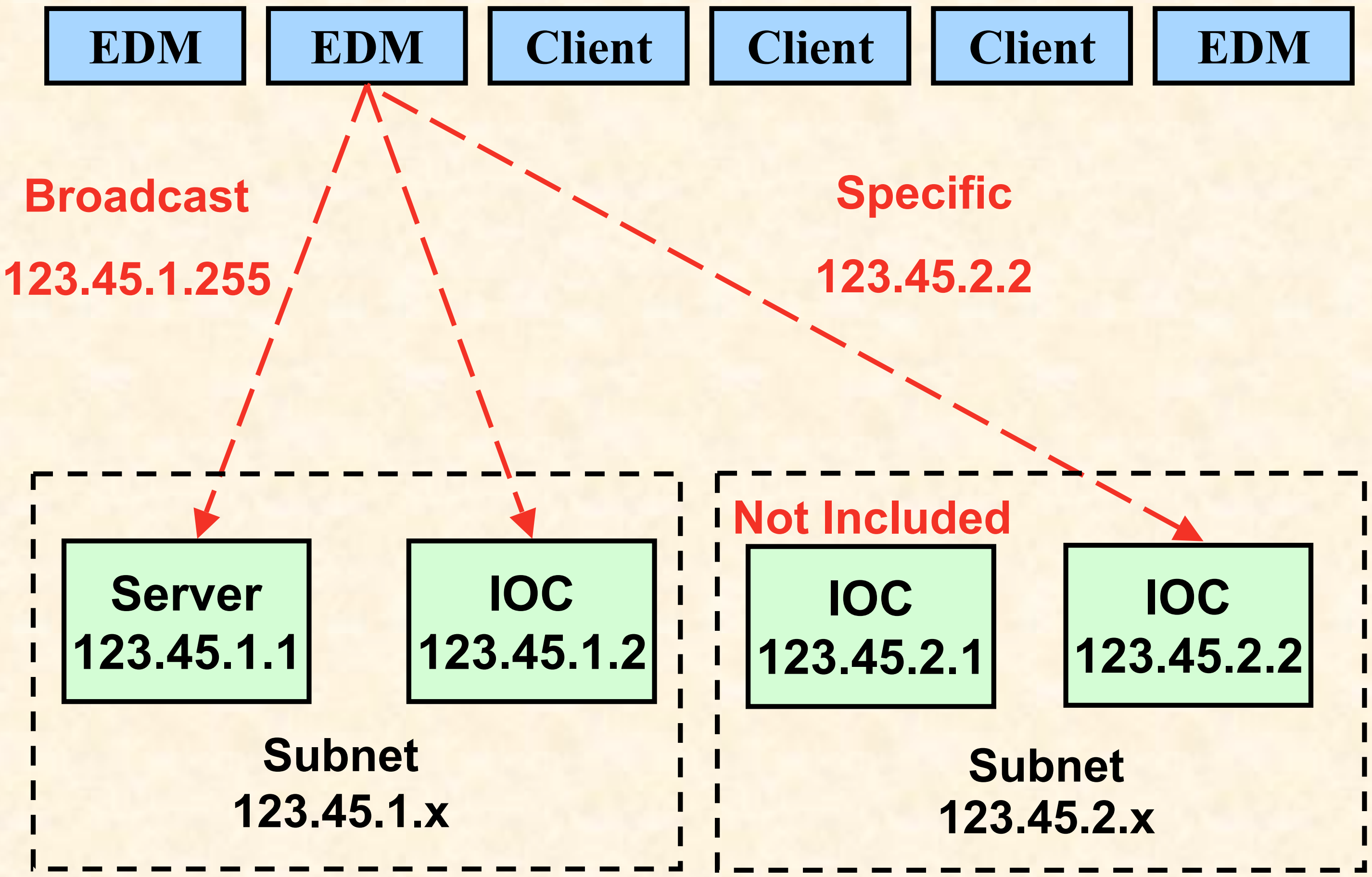


- CA Servers check each search packet
- Usually connects on the first packet or the first few
  - But non-existent PVs cause a lot of traffic
  - Try to eliminate them

Important Environment Variables

- EPICS_CA_ADDR_LIST
  - Determines where to search
  - Is a list (separated by spaces)
    - "123.45.1.255 123.45.2.14 123.45.2.108"
  - Default is broadcast addresses of all interfaces on the host
    - Works when servers are on same subnet as Clients
  - Broadcast address
    - Goes to all servers on a subnet
    - Example: 123.45.1.255
    - Use ifconfig –a on UNIX to find it (or ask an administrator)
- EPICS_CA_AUTO_ADDR_LIST
  - YES: Include default addresses above in searches
  - NO: Do not search on default addresses
  - If you set EPICS_CA_ADDR_LIST, usually set this to NO

EPICS_CA_ADDR_LIST



EDM EDM Client Client Client EDM

Broadcast

123.45.1.255

Specific

123.45.2.2

Server 123.45.1.1

IOC 123.45.1.2

Subnet 123.45.1.x

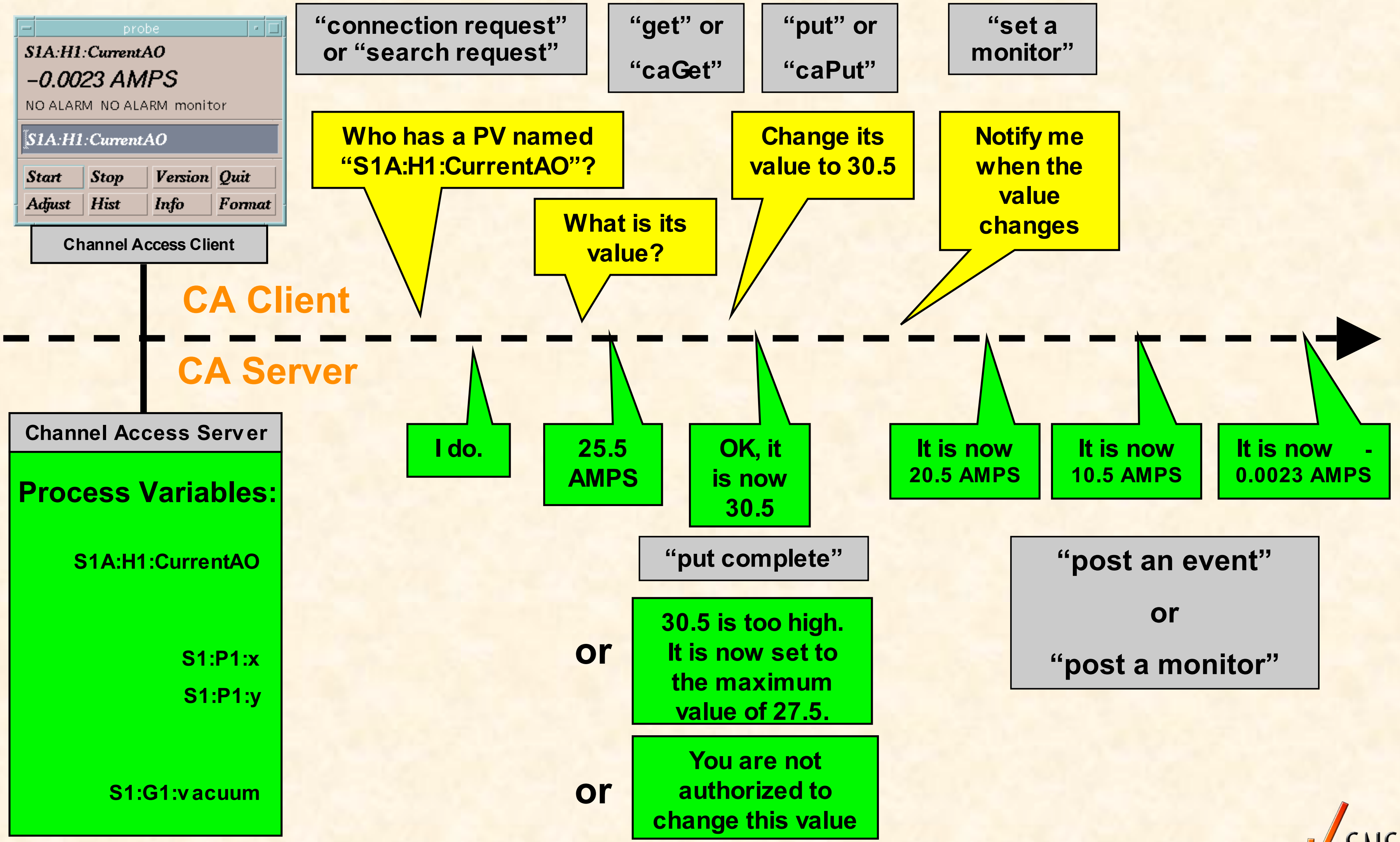
Not Included

IOC 123.45.2.1

IOC 123.45.2.2

Subnet 123.45.2.x

Channel Access in One Slide



probe

S1A:H1:CurrentAO

-0.0023 AMPS

NO ALARM NO ALARM monitor

S1A:H1:CurrentAO

Start Stop Version Quit

Adjust Hist Info Format

Channel Access Client

CA Client

CA Server

Channel Access Server

Process Variables:

S1A:H1:CurrentAO

S1:P1:x

S1:P1:y

S1:G1:vacuum

“connection request” or “search request”

Who has a PV named “S1A:H1:CurrentAO”?

I do.

“get” or “caGet”

What is its value?

25.5 AMPS

“put” or “caPut”

Change its value to 30.5

OK, it is now 30.5

“put complete”

or

30.5 is too high. It is now set to the maximum value of 27.5.

or

You are not authorized to change this value

“set a monitor”

Notify me when the value changes

It is now 20.5 AMPS

It is now 10.5 AMPS

It is now - 0.0023 AMPS

“post an event” or “post a monitor”

Handling of Network Interruptions

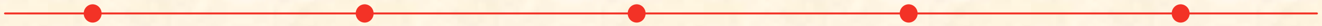
- No Network is up 100%, so CA was designed to handle this:
  - TCP connection closed by server?
    - Notify client code about problem
      - EDM screens turn "white".
    - Client sends new search requests.
  - No data nor beacon from server for 30 sec.?
    - Client sends “Are you there” query
    - If no response for 5 sec, also notify client code, but TCP connection is kept open to avoid network storms.
    - If server eventually sends data: OK. Otherwise we're waiting until the OS cuts the TCP connection (~hours).

Beacons

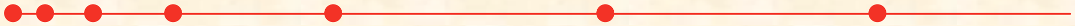
- **Assume all is fine, we are connected, but the data simply doesn't change.**
  - **How do we know the server is still OK?**
- **Assume we searched for a PV, didn't get any response for ~8 minutes.**
  - **How do we learn about a new CA server starting up which might have the missing PV? What triggers renewed search requests?**

Beacons

- UDP broadcast packet sent by a CA Server
- When it is healthy, each Server broadcasts a UDP beacon at regular intervals (like a heartbeat)
  - EPICS_CA_BEACON_PERIOD, 15 s by default



- When it is coming up, each Server broadcasts a startup sequence of UDP beacons
  - Starts with a small interval (25 ms, 75 ms for VxWorks)
  - Interval doubles each time
  - Until it gets larger than 15 s, then it stays at 15 s
    - Takes about 10 beacons and 40 s to get to steady state



- Clients monitor the beacons
  - Receive beacons: Server is OK.
  - Receive new beacons at changing intervals: Beacon anomaly, new CA server, reissue searches.

casw - CA Server Watcher

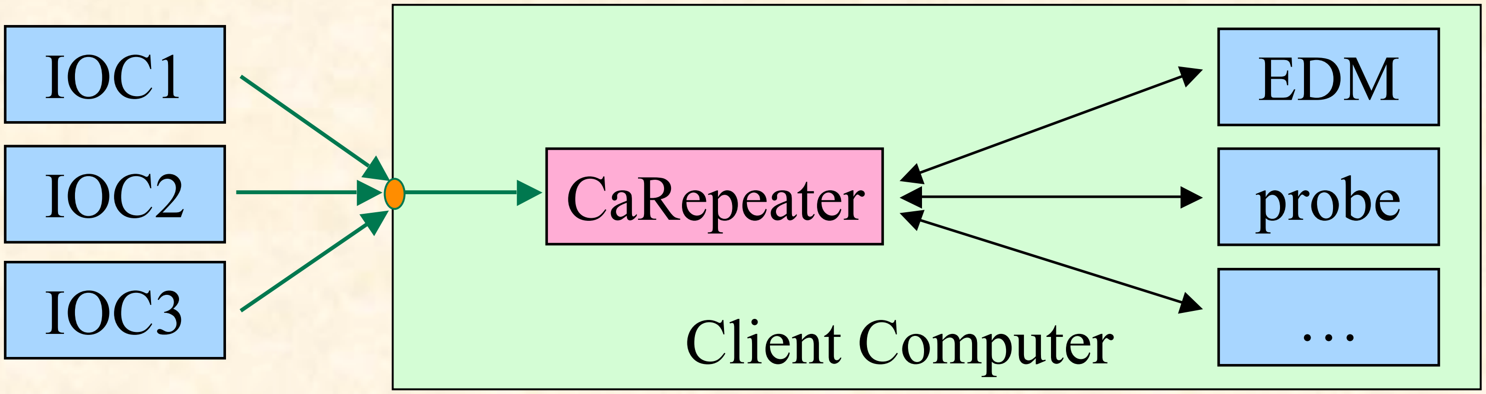
- Command-line tool in EPICS base
- Run "casw -i 2"
- Prints every received beacon
  - For each CA server, expect one every 15 seconds.
- Marks anomalies with "*"
  - There should be very few,
    - unless you (re)start an IOC,
    - or a faulty clock on a CA server causes it to send irregular beacons,
    - or some network configuration feature causes beacons to arrive multiple times.

Issues

- CA Client does not connect
  - Check basic network connectivity.
    - Can server and client machines 'ping' each other?
    - Check EPICS_CA_ADDR_LIST if server is on different subnet.
- CA Client does not re-connect after network issue or IOC reboot
  - Use casw. Does the client computer receive the (anomal) beacons of the rebooting IOC?
  - Check EPICS_CAS_BEACON_ADDR_LIST, since routers will not forward beacons across subnets.
  - Check if 'caRepeater' is running on the client.

caRepeater?

- Older OSs didn't allow multiple programs to listen to the same UDP port
  - They didn't see the beacons (UDP broadcasts)!
- caRepeater solves this problem
  - There is one caRepeater process per workstation
  - Clients make a TCP connection to it when they start up
  - caRepeater receives the beacons
    - EPICS_CA_REPEATER_PORT[usually 5065]
  - .. and forwards them to clients.



caSnooper

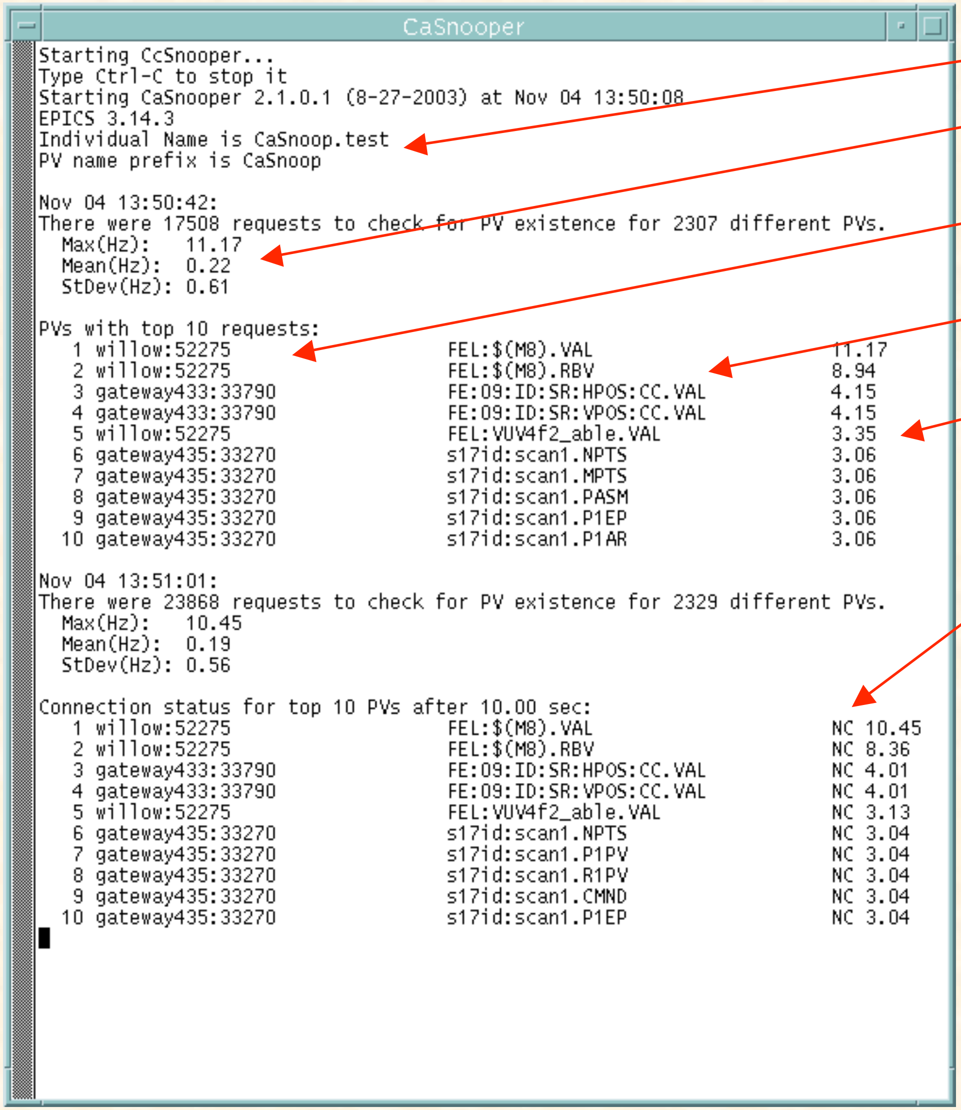
- … is an EPICS extension for displaying CA search requests on the network.
  - Use to cleanup EDM screens or IOCs that keep looking for non-existing PVs
    - because of a PV name typo
    - because PV was removed/renamed for a reason
  - Use to check if you non-resolving CA client actually sends out search requests
    - Run caSnooper in the 'target' subnet to see if the search requests reach there.
- Pam Gurd is the SNS caSnooper expert.

caSnooper output

Two lines from RunCaSnooper →

Print top 10 (-p10) →

Check top 10 (-c10) →



```
Starting CcSnooper...
Type Ctrl-C to stop it
Starting CaSnooper 2.1.0.1 (8-27-2003) at Nov 04 13:50:08
EPICS 3.14.3
Individual Name is CaSnoop.test
PV name prefix is CaSnoop

Nov 04 13:50:42:
There were 17508 requests to check for PV existence for 2307 different PVs.
  Max(Hz):    11.17
  Mean(Hz):   0.22
  StDev(Hz):  0.61

PVs with top 10 requests:
   1 willow:52275                   FEL:$(M8).VAL                    11.17
   2 willow:52275                   FEL:$(M8).RBV                    8.94
   3 gateway433:33790               FE:09:ID:SR:HPOS:CC.VAL          4.15
   4 gateway433:33790               FE:09:ID:SR:VPOS:CC.VAL          4.15
   5 willow:52275                   FEL:VUV4f2_able.VAL              3.35
   6 gateway435:33270               s17id:scan1.NPTS                 3.06
   7 gateway435:33270               s17id:scan1.MPTS                 3.06
   8 gateway435:33270               s17id:scan1.PASM                 3.06
   9 gateway435:33270               s17id:scan1.P1EP                 3.06
  10 gateway435:33270               s17id:scan1.P1AR                 3.06

Nov 04 13:51:01:
There were 23868 requests to check for PV existence for 2329 different PVs.
  Max(Hz):    10.45
  Mean(Hz):   0.19
  StDev(Hz):  0.56

Connection status for top 10 PVs after 10.00 sec:
   1 willow:52275                   FEL:$(M8).VAL                    NC 10.45
   2 willow:52275                   FEL:$(M8).RBV                    NC 8.36
   3 gateway433:33790               FE:09:ID:SR:HPOS:CC.VAL          NC 4.01
   4 gateway433:33790               FE:09:ID:SR:VPOS:CC.VAL          NC 4.01
   5 willow:52275                   FEL:VUV4f2_able.VAL              NC 3.13
   6 gateway435:33270               s17id:scan1.NPTS                 NC 3.04
   7 gateway435:33270               s17id:scan1.P1PV                 NC 3.04
   8 gateway435:33270               s17id:scan1.R1PV                 NC 3.04
   9 gateway435:33270               s17id:scan1.CMND                 NC 3.04
  10 gateway435:33270               s17id:scan1.P1EP                 NC 3.04
```

individual name, prefix

statistics

machine:port, (can be used to identify source)

name

search rate in Hz

Not connected, will be C for connected (hardly ever the case)

CA Environment Variables

- CA Client

EPICS_CA_ADDR_LIST

EPICS_CA_AUTO_ADDR_LIST

EPICS_CA_CONN_TMO

EPICS_CA_BEACON_PERIOD

EPICS_CA_REPEATER_PORT

EPICS_CA_SERVER_PORT

EPICS_CA_MAX_ARRAY_BYTES

EPICS_TS_MIN_WEST

- CA Server

EPICS_CAS_SERVER_PORT

EPICS_CAS_AUTO_BEACON_ADDR_LIST

EPICS_CAS_BEACON_ADDR_LIST

EPICS_CAS_BEACON_PERIOD

EPICS_CAS_BEACON_PORT

EPICS_CAS_INTF_ADDR_LIST

EPICS_CAS_IGNORE_ADDR_LIST

- See the Channel Access Reference Manual for more information

What is a PV (Channel)?

- Whenever there's a CA server out there which decides to respond to a search request, that's a PV!
- iocCore responds to "{record}.{field}" searches if
  - the {record} is for a record on this IOC,
  - and the {field} is an accessible field of that record,
  - or it's the pseudo-field "RTYP" (record type).
- So (almost) every field of every record is a PV.
- But you can implement your own CA server based on the CAS library (for C++), and then you decide when to respond!
  - This used to be important when iocCore only ran on vxWorks, so the 'portable' CAS lib was used to serve data from Linux, Win32, VMS, …
    Now it's probably better to implement device support and run iocCore.

Channel Properties

- Each channel comes with properties:
  - Value
    - of type string or double or int or …
    - Scalar or array
  - Time stamp
    - Up to nanosecond precision
  - Severity code
    - OK, MINOR, MAJOR, or INVALID
  - Status code to qualify the severity
    - OK, READ error, WRITE error, at HIGH limit, …
  - units, suggested display range, control limits, alarm limits.

Client interface to properties

- The available properties are fixed.
  - One cannot add a new 'color' property.
- The request types are fixed.
  - "DBR_…" types.
  - Available:
    - Just value.
    - Value with status and severity.
    - Value with status, severity and time stamp.
    - "Everything:" value, units, time, status, limits, …
  - Not available:
    - Custom combinations like value with units.

Records & Fields vs. Channels & Properties

- A CA client asks for the properties of a channel.
- The implementer of the CA server decides how to answer.
- The iocCore implementation maps the fields of a record to the properties of a channel.
  - Details are in the source code for the respective record type. Not always predictable or meaningful!

Example: AI record "fred"

- PV "fred" or "fred.VAL"
  - value property of channel = VAL field of record.
    - Type double, one element (scalar).
  - time property = TIME field
  - status = STAT
  - Severity = SEVR
  - units = EGU
  - Precision = PREC
  - display limit low, high = LOPR, HOPR
  - control limit low, high = LOPR, HOPR
  - alarm limits = LOLO, LOW, HIGH, HIHI

- Makes a lot of sense.
  - EDM can display the value together with units, formatted according to the precision, as e.g. "12.37 volts".
  - StripTool can use display limits for initial Y axis range.

Example: AI record "fred"

- PV "fred.SCAN"
  - value property of channel = SCAN field of record.
    - Type enumerated, values: "Passive", "1 second", ...
  - time property = TIME field
  - status = STAT
  - Severity = SEVR
  - units = EGU
  - Precision = 0
  - display limit low, high = 0, 65535
  - control limit low, high = 0, 65535
  - alarm limits = 0, 0, 0, 0

- Makes some sense, but
  - Units don't really apply to the SCAN field.
  - It's value range is really limited by the available SCAN choices, not 0..65535.

Points to remember

- In 99% of the cases, CA "just works"
  - If not, check EPICS_CA_ADDR_LIST
  - If that's not it, there could be a subnet/router issue with UDP search broadcasts and beacons.
- Channel/property and Record/field are different things!
  - This decouples the CA clients from the IOC database and its record types, allowing EPICS collaborators to share CA client tools for vastly different records and databases.
  - But also means that CA clients have no idea about records nor fields.
    - EDM doesn't know that there might be a "readback" AI that goes with a "setpoint" AO record.
    - The archiver archives channels and their properties, not a whole AI or motor record.
    - Important properties for dealing with waveform data is definitely missing (sample rate, type of data).

Acknowledgements

- Material and ideas have been copied from
  - Ned Arnold (APS)
  - Ken Evans (APS)