dCache.org

Implementing a high-end NFSv4.1 service using a Java NIO framework

In 7500 lines to new RPC library

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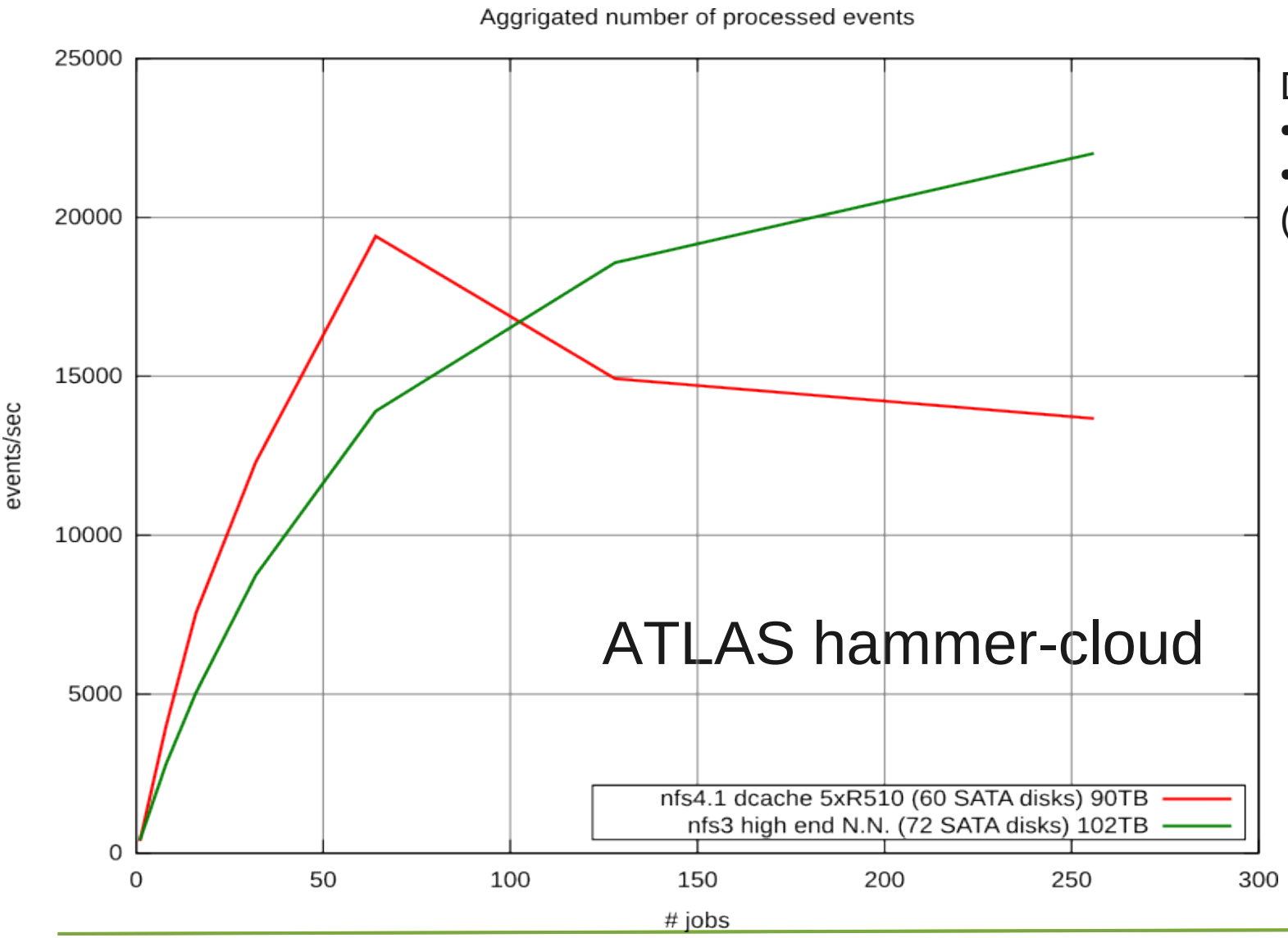
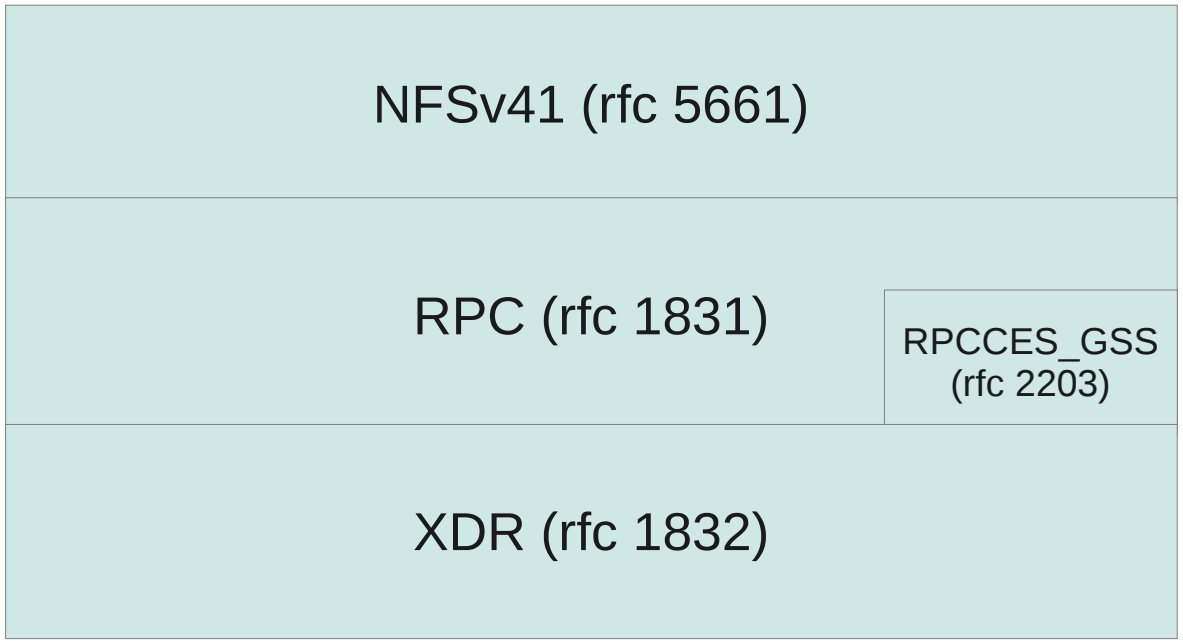
dCache NFS vs. N.N



DESY GridLab:
- 50% T2 CPU
- 30% T2 Storage

(See poster 503)

The anatomy of NFS package



A bit of ONC-RPC history

- Developed by Sun Microsystems in 1986
- First published in 1988 (as Sun RPC)
- Re-published as standard in 1995 (as ONC RPC)
- ~1600 registered services at IANA
  - NFS
  - NIS
- Widely used at HEP in 90's
  - Control, DAQ, Monitoring, Data transfer

Today status

- Pushed back by new 'Buzz Words'
  - XML-RPC & JSON-RPC
  - SOAP & REST
- Performance still not bitten
- Google's Protobuff is real alternative
  - String type
  - Modern language friendly
  - No service version number
  - Encode/Decode only (more like XDR)

Why invent a new wheel?

- Not that many Java implementations
  - No bi-directional RPC support
  - No RPCSEC_GSS
  - Not up-to-date
- Official libtirpc not good enough
  - No bi-directional RPC
  - JAVA – C integration

Is it a square wheel?

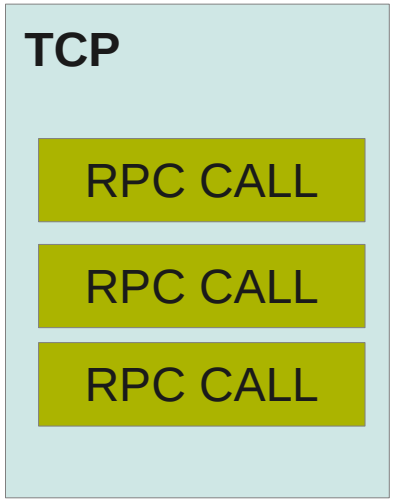
- High performance network IO is not an RPC/NFS requirements
  - `Network components from GlassFish Application Server`
- RFC 1831 and RFC 2203 compliant
- IPv6 support
- GSS handling comes from Java Run-time Environment
  - `jre 6 provides AES128 and AES256`
- Poll/epoll/select/p_threads handles by JVM
  - `We use high level abstractions`
- Works on Linux, Solaris, OS X, Windows and Android

We are not doing it the typical JAVA way

- Single thread per connection
  - Thousand threads per server
- Request processed almost in a single thread
  - No thread fencing (till first shared resource)
- Simple to implement
  - Blocking reads
  - Blocking writes
  - Idle threads costs nothing (ok, 48k stack space)

RPC vs. Others

- Many protocols are request-reply based
- No new requests as long as no reply
- Multiple requests processed sequentially

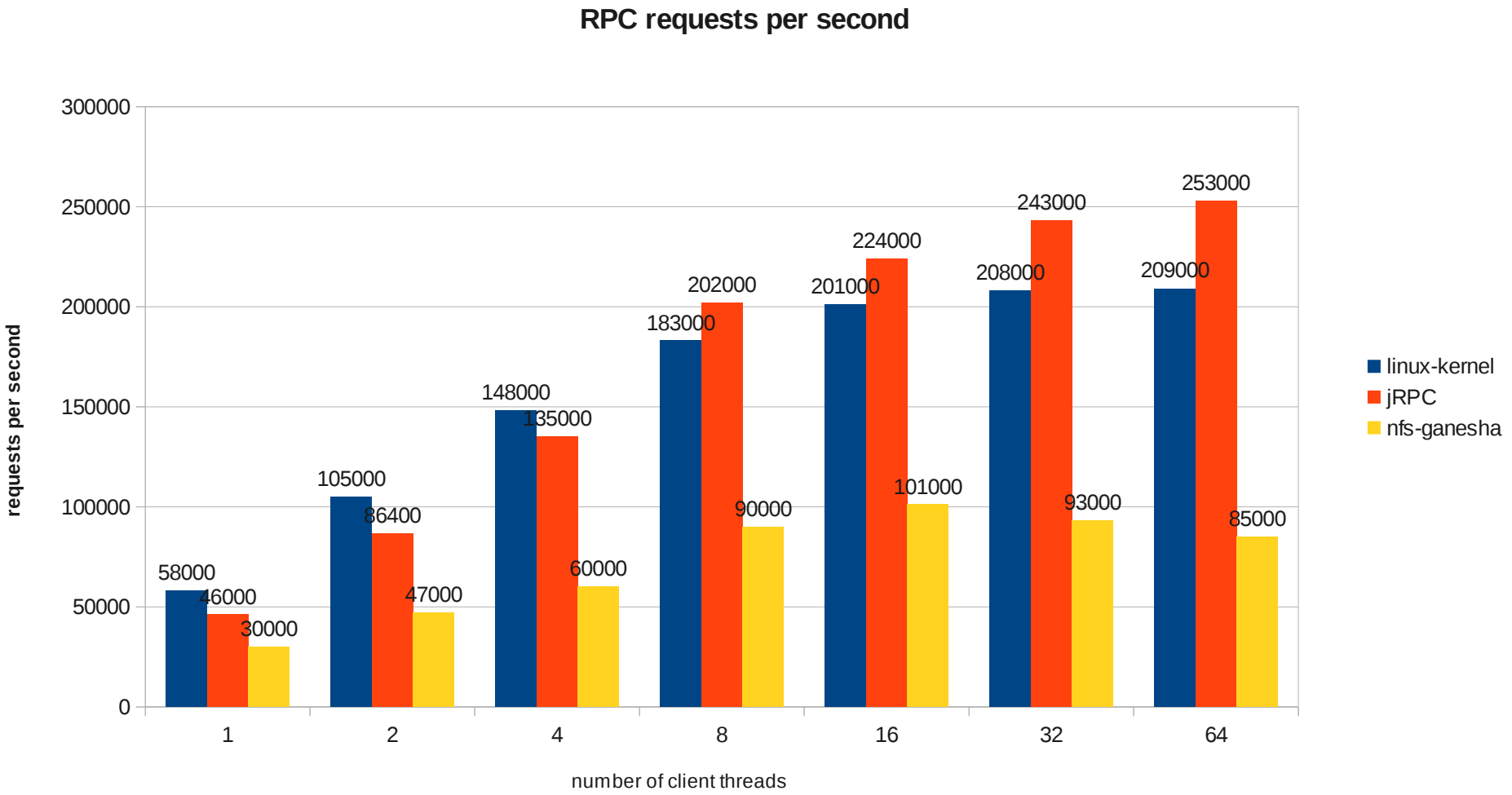


- Possible multiple independent requests
  - ➔ Even in one TCP package
- Server may process requests out-of-order
  - ➔ Reply in asynchronous fashion
- THE way to go for some workloads
  - ➔ High latency High bandwidth NFS access

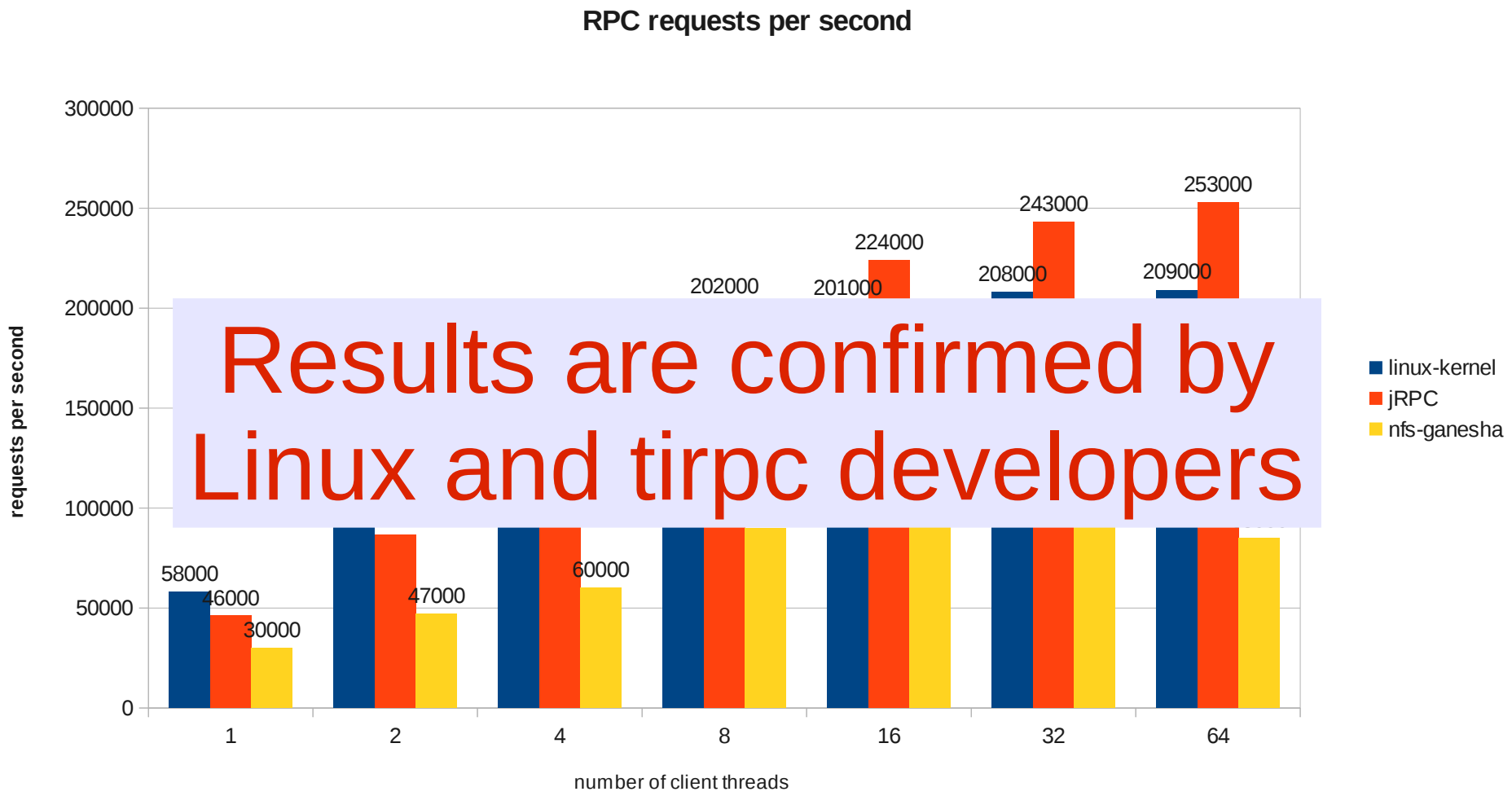
Our approach

- Poll of IO threads
  - Typically set to #Cores
- Pool of worker threads (if required)
- Processing per PRC packet
  - No binding to network connection
  - Can be used with other transport (RDMA)
- Event based
  - doOnRead if bytes arrived
  - doOnWrite if bytes sent

jRPC vs. Linux kernel

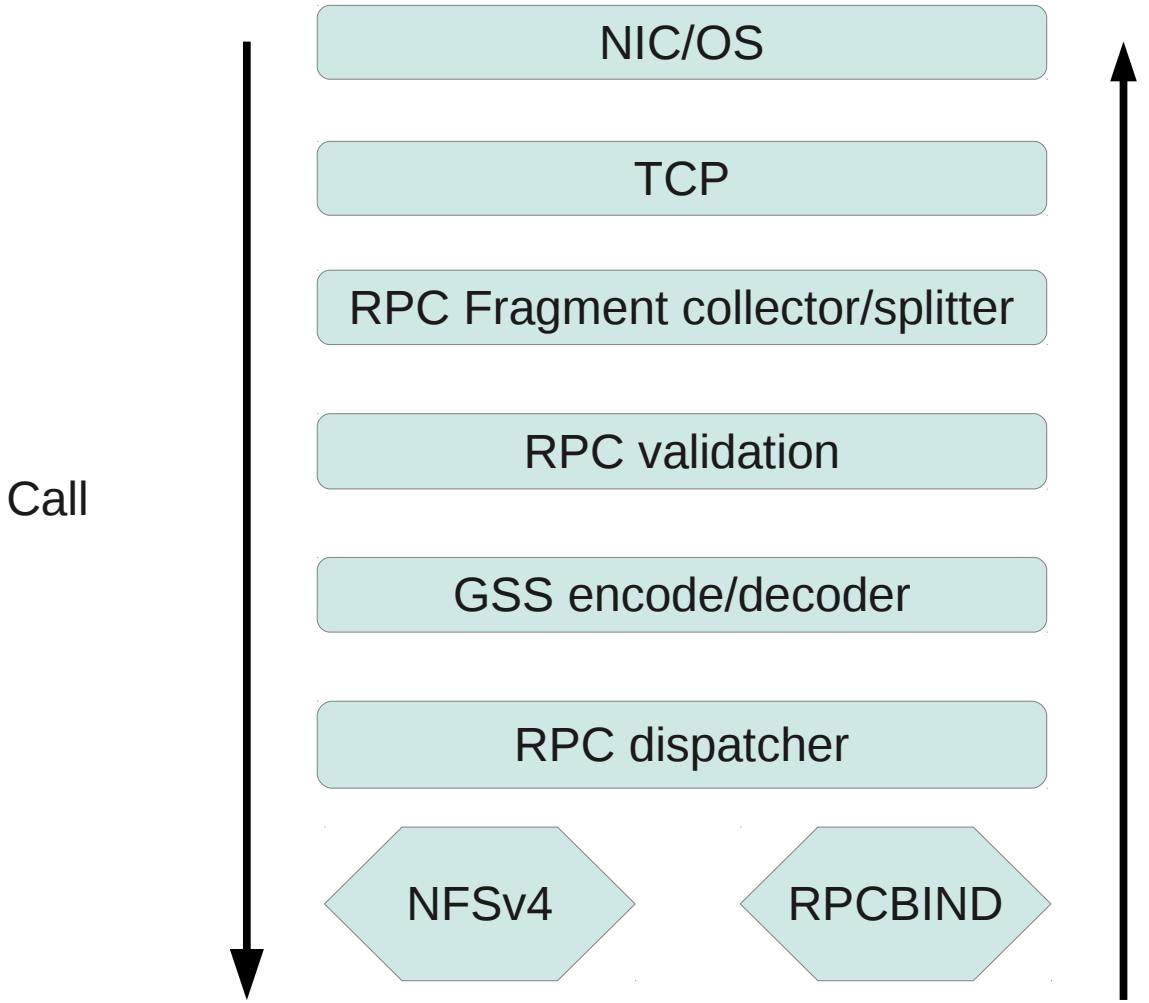


jRPC vs. Linux kernel



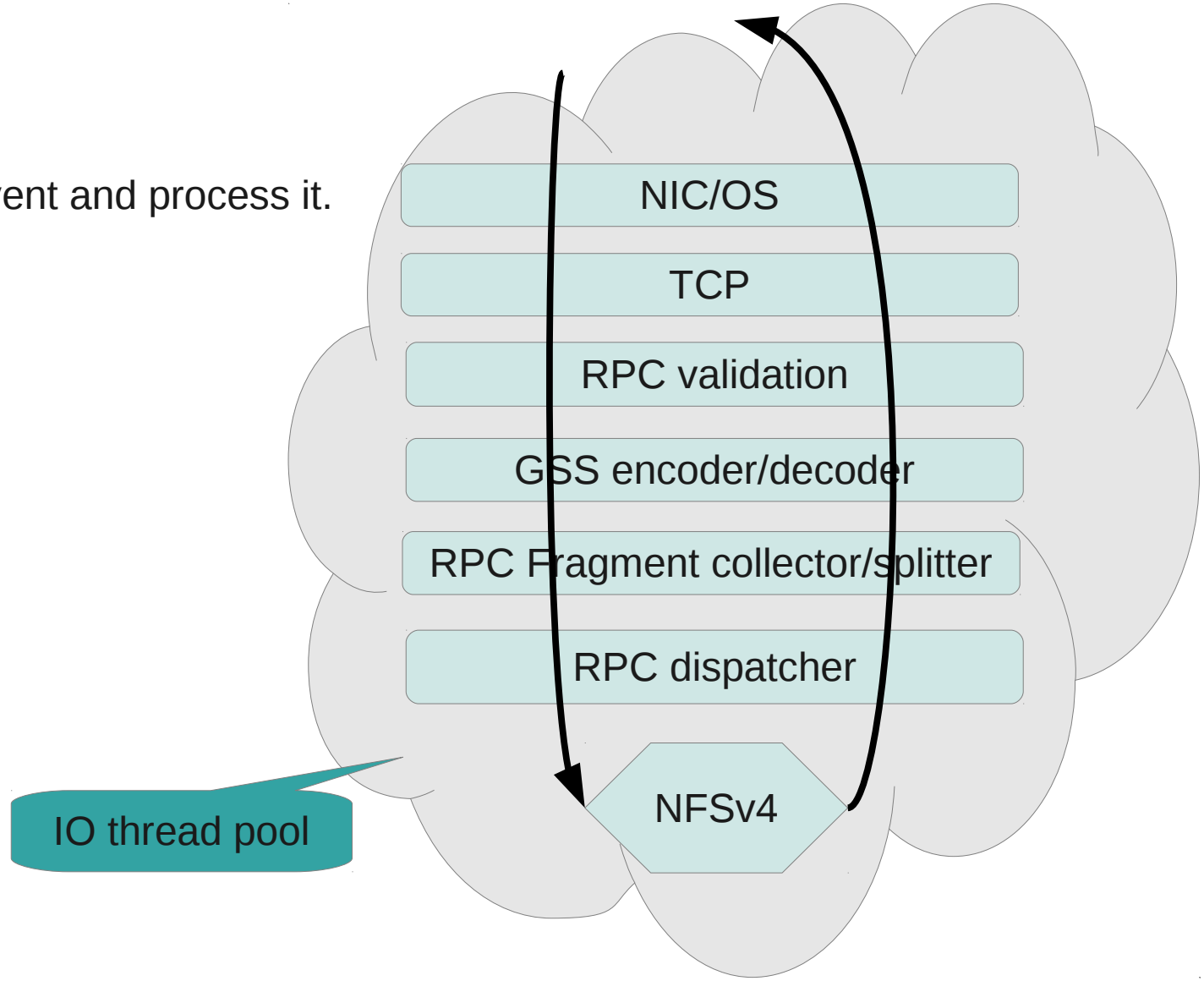
Results are confirmed by Linux and tirpc developers

Chain of responsibilities



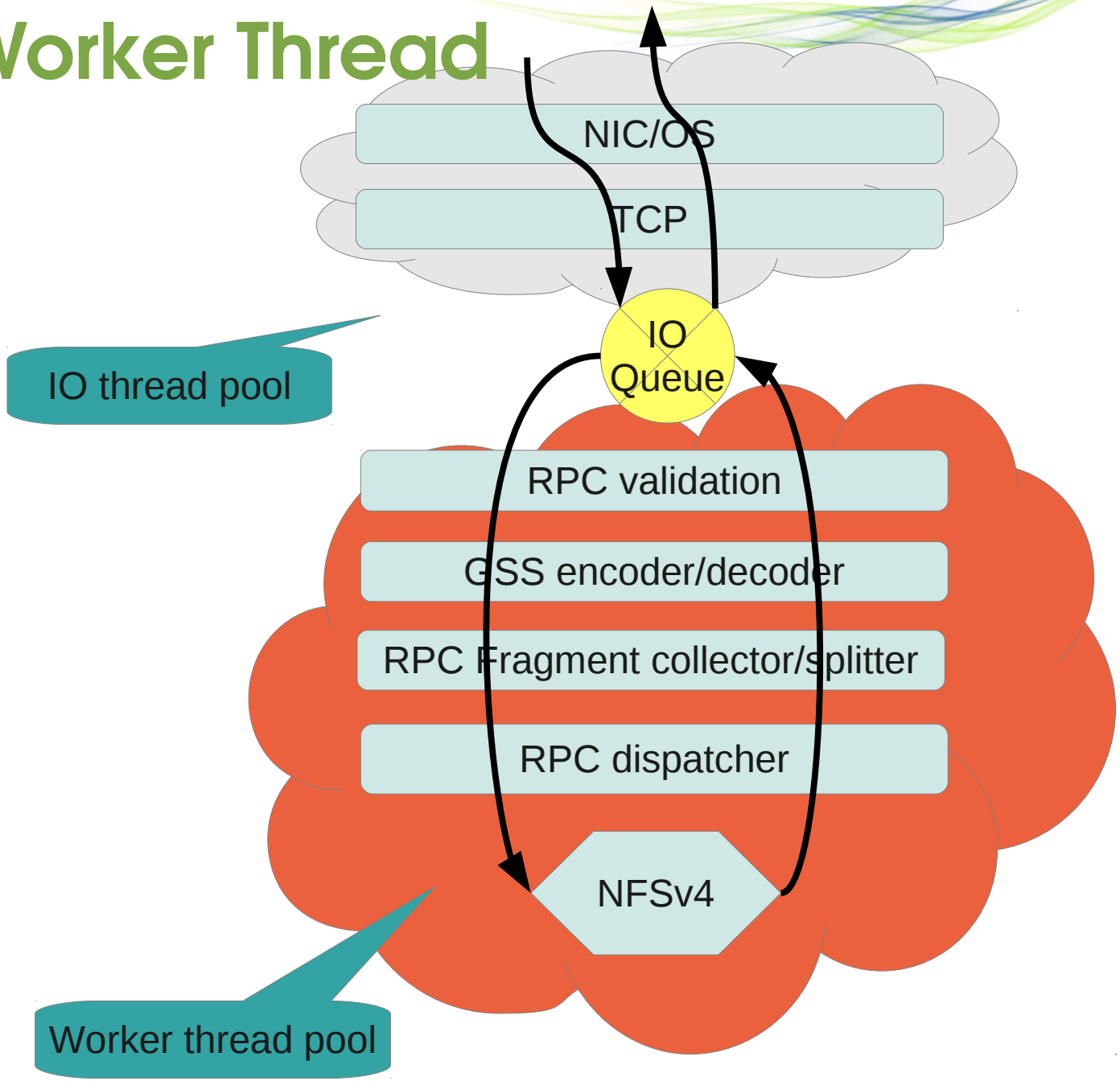
IO strategy: Same Thread

Single thread pick-ups an event and process it.



IO strategy: Worker Thread

A thread pick-ups an event and pushed it into event queue.



Multi-Core

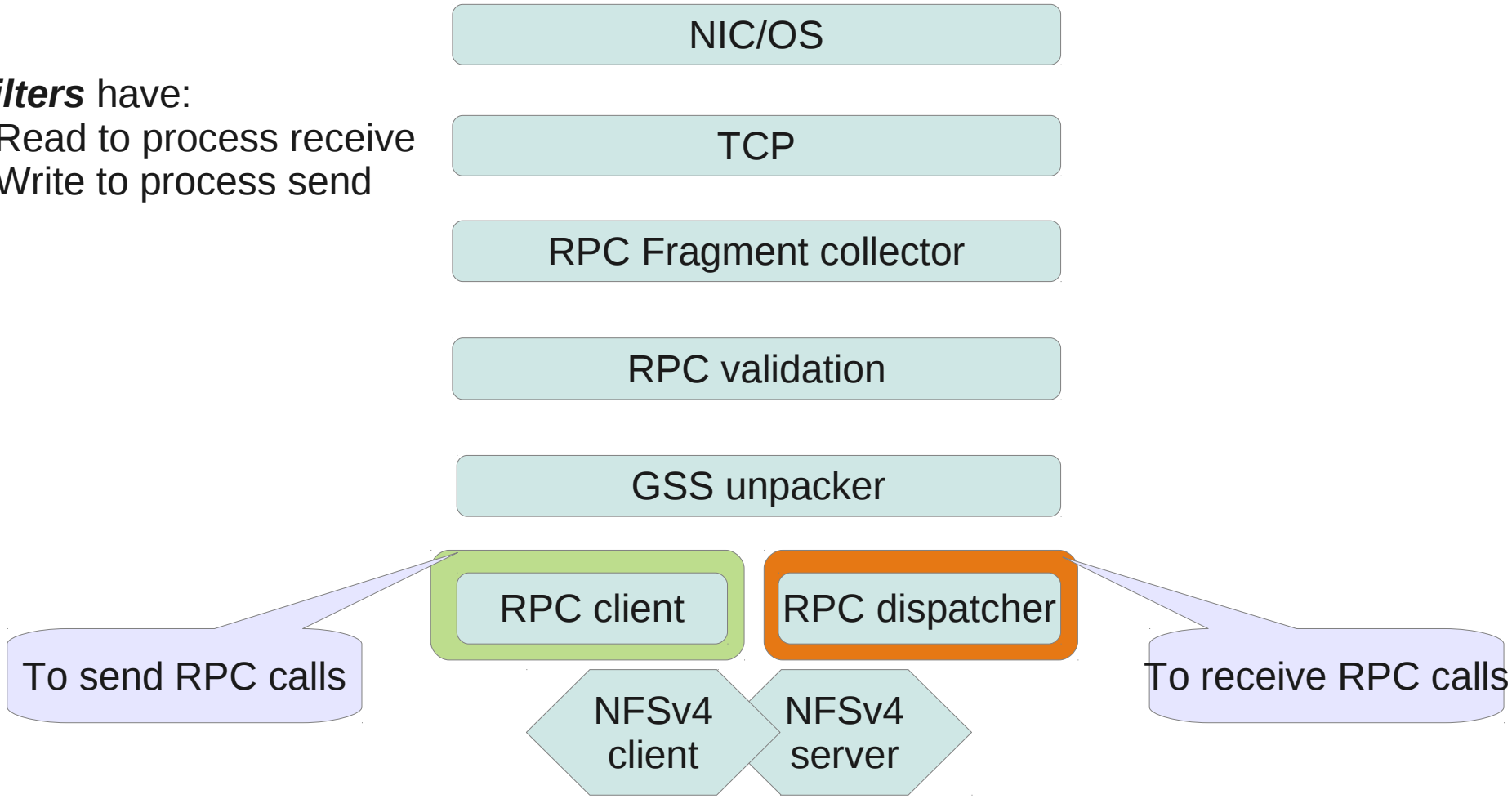
```
top - 13:39:55 up 7 days, 20:40,  3 users,  load average: 8.38, 8.52, 9.27
Tasks: 279 total,   1 running, 278 sleeping,   0 stopped,   0 zombie
Cpu0  : 30.6%us, 18.6%sy,  0.0%ni, 45.5%id,  0.0%wa,  0.0%hi,  5.3%si,  0.0%st
Cpu1  : 24.7%us, 14.7%sy,  0.0%ni, 57.7%id,  0.0%wa,  0.0%hi,  3.0%si,  0.0%st
Cpu2  : 23.5%us, 14.2%sy,  0.0%ni, 59.6%id,  0.0%wa,  0.0%hi,  2.6%si,  0.0%st
Cpu3  : 24.5%us, 14.9%sy,  0.0%ni, 57.6%id,  0.0%wa,  0.0%hi,  3.0%si,  0.0%st
Cpu4  : 30.9%us, 20.6%sy,  0.0%ni, 43.5%id,  0.0%wa,  0.0%hi,  5.0%si,  0.0%st
Cpu5  : 22.9%us, 14.6%sy,  0.0%ni, 59.5%id,  0.0%wa,  0.0%hi,  3.0%si,  0.0%st
Cpu6  : 17.8%us, 10.9%sy,  0.0%ni, 69.3%id,  0.0%wa,  0.0%hi,  2.0%si,  0.0%st
Cpu7  : 25.5%us, 14.6%sy,  0.0%ni, 56.3%id,  0.0%wa,  0.0%hi,  3.6%si,  0.0%st
Cpu8  : 25.6%us, 20.6%sy,  0.0%ni, 49.2%id,  0.0%wa,  0.0%hi,  4.7%si,  0.0%st
Cpu9  : 22.8%us, 13.5%sy,  0.0%ni, 60.7%id,  0.0%wa,  0.0%hi,  3.0%si,  0.0%st
Cpu10 : 18.8%us, 11.6%sy,  0.0%ni, 67.7%id,  0.0%wa,  0.0%hi,  2.0%si,  0.0%st
Cpu11 : 18.8%us, 11.9%sy,  0.0%ni, 67.3%id,  0.0%wa,  0.0%hi,  2.0%si,  0.0%st
Cpu12 :  1.3%us,  4.0%sy,  0.0%ni,  0.7%id,  0.0%wa,  0.0%hi, 94.0%si,  0.0%st
Cpu13 : 14.2%us,  7.6%sy,  0.0%ni, 76.2%id,  0.0%wa,  0.0%hi,  2.0%si,  0.0%st
Cpu14 : 22.8%us, 14.9%sy,  0.0%ni, 58.9%id,  0.0%wa,  0.0%hi,  3.3%si,  0.0%st
Cpu15 : 21.5%us, 11.9%sy,  0.0%ni, 63.9%id,  0.0%wa,  0.0%hi,  2.6%si,  0.0%st
Mem:  66070260k total, 14979240k used, 51091020k free,   295776k buffers
Swap:  8008392k total,        0k used,  8008392k free, 13926660k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
17425 root      16   0 16.3g 191m 9728 S 619.0  0.3  62:00.15 java
17618 root      15   0  6024  676  572 S 83.7  0.0   5:50.02 bitguard
17593 root      15   0 12892 1256  828 R  1.0  0.0   0:04.72 top
 5463 root      18   0 21192 1388  548 S  0.3  0.0   0:09.80 pcscd
    1 root      15   0 10368  684  572 S  0.0  0.0   0:03.27 init
```

How that looks like in the code

```
RpcDispatchable nfs4 = new NFSServerV41(....);
OncRpcSvc svc = new OncRpcSvcBuilder()
        .withTCP()
        .withAutoPublish()
        .withPort(2049)
        .withSameThreadIoStrategy()
        .build();
svc.register(nfs4_prot.NFS4_PROGRAM, nfs4);
svc.start();
```

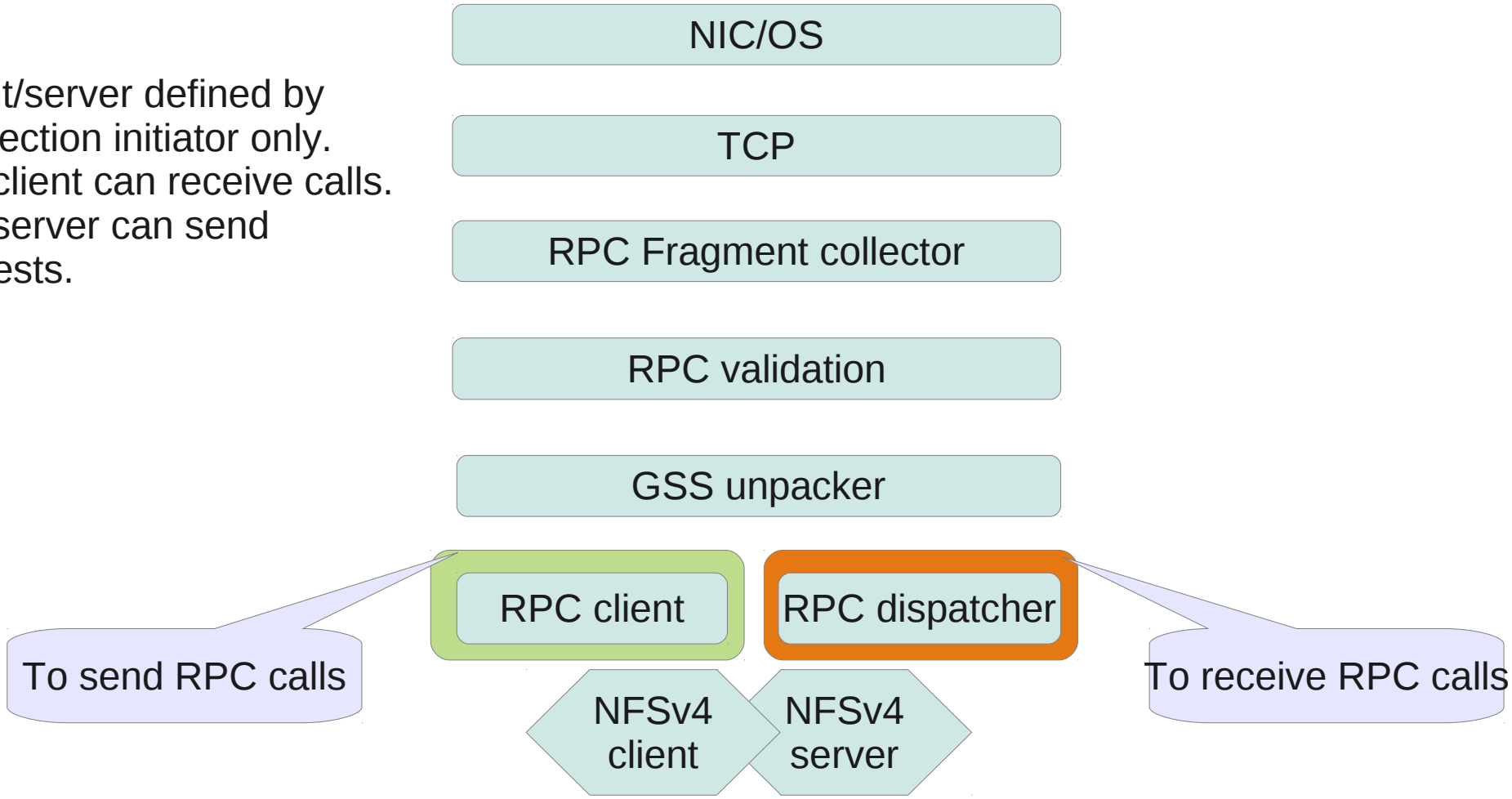
Code re-use (and much more)

- All ***Filters*** have:
  - onRead to process receive
  - onWrite to process send



Bi-directional RPC

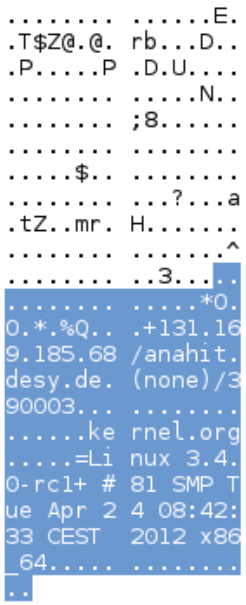
- Client/server defined by connection initiator only.
- Any client can receive calls.
- Any server can send requests.



Security

- RPCSEC_GSS (krb5)
- Proofed to work with AD, MIT and Heimdal
- Supported Quality of protection:
  - `NONE`
  - `INTEGRITY`
  - `PRIVACY`

QOP none


....E.
.T$Z@.@. rb...D..
.P.....P .D.U....
....N..
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....?...a
.tZ..mr. H.....
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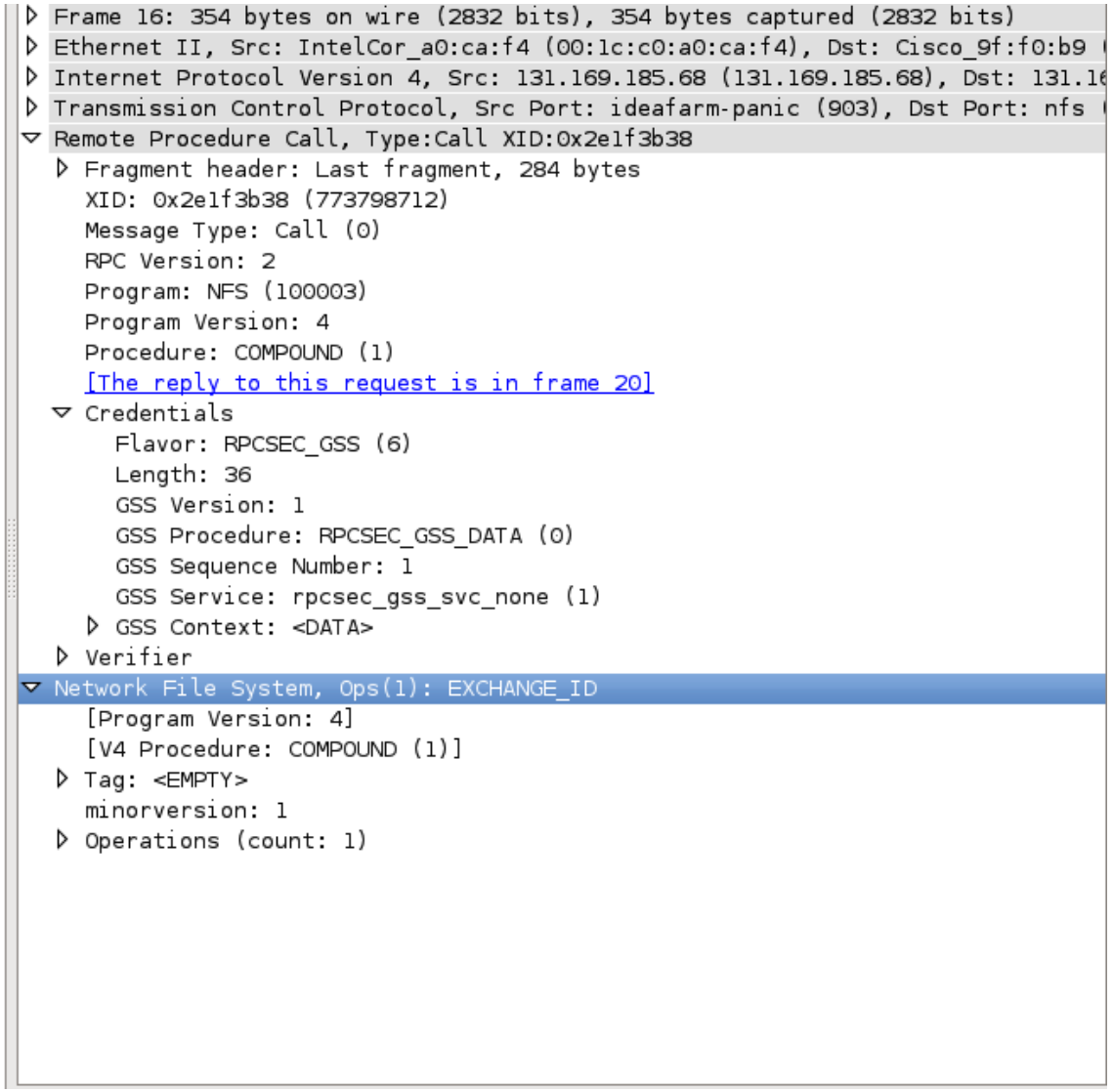
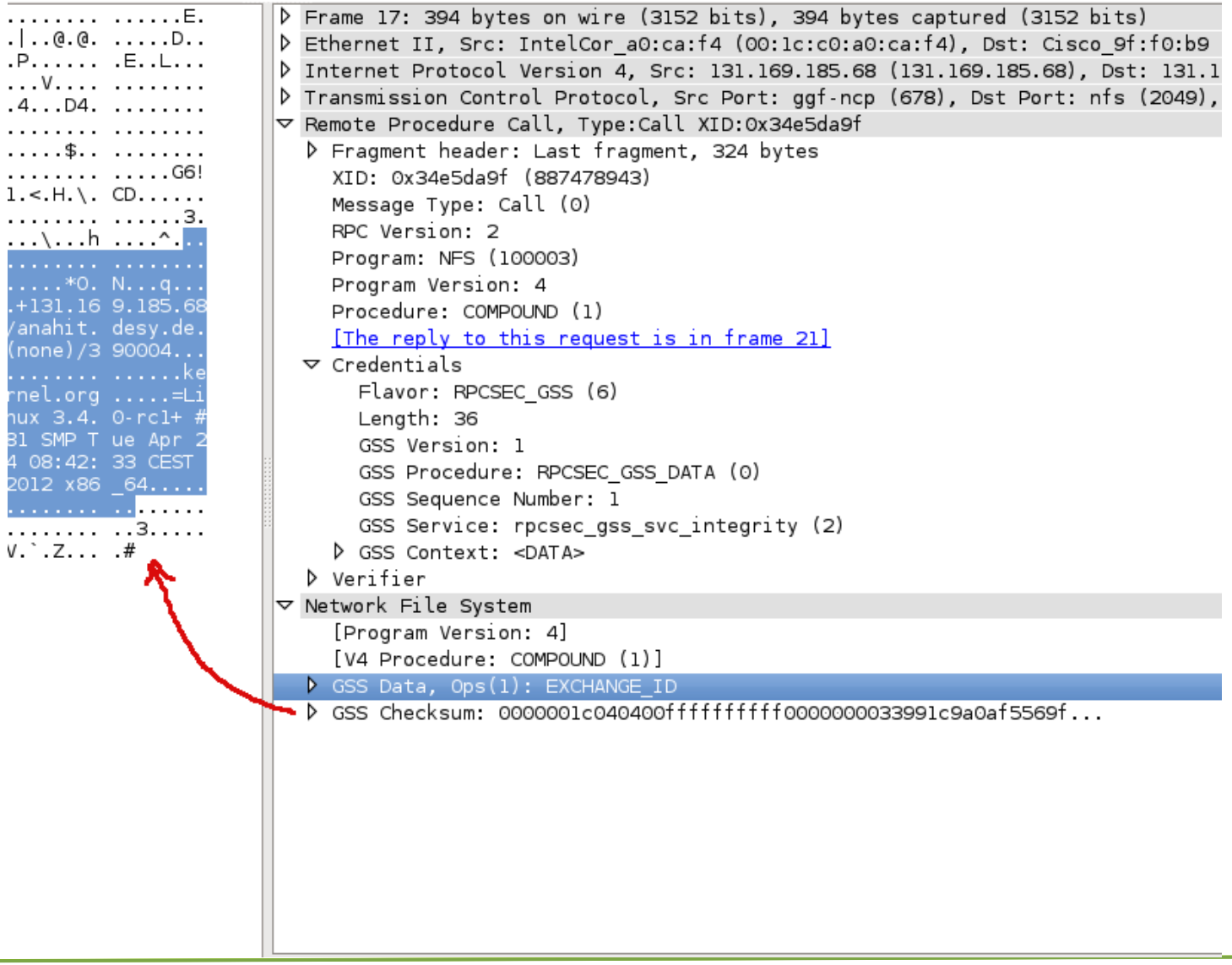
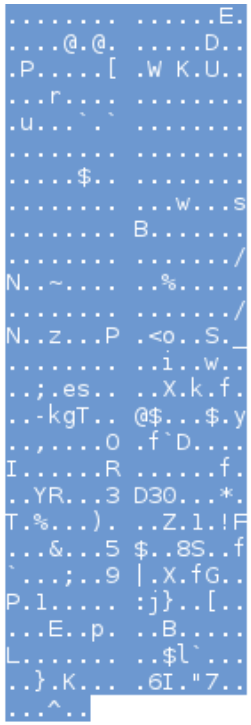
....3.....
....*0.
0.*.%Q.. .+131.16
9.185.68 /anahit.
desy.de. (none)/3
90003... .....
.....ke rnel.org
.....=Li nux 3.4.
0-rc1+ # 81 SMP T
ue Apr 2 4 08:42:
33 CEST 2012 x86
_64..... .....
..


Frame 16: 354 bytes on wire (2832 bits), 354 bytes captured (2832 bits)
Ethernet II, Src: IntelCor_a0:ca:f4 (00:1c:c0:a0:ca:f4), Dst: Cisco_9f:f0:b9
Internet Protocol Version 4, Src: 131.169.185.68 (131.169.185.68), Dst: 131.16
Transmission Control Protocol, Src Port: ideafarm-panic (903), Dst Port: nfs
Remote Procedure Call, Type:Call XID:0x2e1f3b38
Fragment header: Last fragment, 284 bytes
XID: 0x2e1f3b38 (773798712)
Message Type: Call (0)
RPC Version: 2
Program: NFS (100003)
Program Version: 4
Procedure: COMPOUND (1)
[The reply to this request is in frame 20]
Credentials
Flavor: RPCSEC_GSS (6)
Length: 36
GSS Version: 1
GSS Procedure: RPCSEC_GSS_DATA (0)
GSS Sequence Number: 1
GSS Service: rpcsec_gss_svc_none (1)
GSS Context: <DATA>
Verifier
Network File System, Ops(1): EXCHANGE_ID
[Program Version: 4]
[V4 Procedure: COMPOUND (1)]
Tag: <EMPTY>
minorversion: 1
Operations (count: 1)

QOP integrity



QOP privacy



```
Frame 17: 422 bytes on wire (3376 bits), 422 bytes captured (3376 bits)
Ethernet II, Src: IntelCor_a0:ca:f4 (00:1c:c0:a0:ca:f4), Dst: Cisco_9f:
Internet Protocol Version 4, Src: 131.169.185.68 (131.169.185.68), Dst:
Transmission Control Protocol, Src Port: 1018 (1018), Dst Port: nfs (20
Remote Procedure Call, Type:Call XID:0x9160b1e2
  Fragment header: Last fragment, 352 bytes
    XID: 0x9160b1e2 (2439033314)
    Message Type: Call (0)
    RPC Version: 2
    Program: NFS (100003)
    Program Version: 4
    Procedure: COMPOUND (1)
    [The reply to this request is in frame 21]
  Credentials
      Flavor: RPCSEC_GSS (6)
      Length: 36
      GSS Version: 1
      GSS Procedure: RPCSEC_GSS_DATA (0)
      GSS Sequence Number: 1
      GSS Service: rpcsec_gss_svc_privacy (3)
    GSS Context: <DATA>
  Verifier
Network File System
    [Program Version: 4]
    [V4 Procedure: COMPOUND (1)]
  GSS Data: <DATA>
```

SUMMARY

- High performance RPC library
- Compatible with existing standards
- Meets today's requirements
  - `IPv6, AES256`
- In production since 2009 (dCache-1.9.5)

Ready to use by others

- Spitted into an independent library
- Licensed with LGPLv2
- Hosted on http://code.google.com/p/nio-jrpc/
- Maven repo.
- Already used in third party products
  - BACnet
  - One of the Swiss banks

Wild Slides

dCache in one slide