TIPC

Transparent Inter Process Communication

by Jon Maloy

PRESENTATION OVERVIEW

- **Introduction to TIPC**
- **Demo**
- **Current status**
- **Roadmap 2015-2016**

TIPC FEATURES

"All-in-one" L2 based messaging service

- → Reliable datagram unicast, anycast and multicast
- → Connections with stream or message transport
- → Location transparent service addressing
- → Multi-binding of addresses
- → Immediate auto-adaptation/failover after network changes

Service and Topology tracking function

- → Nodes, processes, sockets, addresses, connections
- → Immediate feedback about service availability or topology changes
- → Subscription/event function for service addresses
- → Fully automatic neighbor discovery

TIPC == SIMPLICITY

No need to configure or lookup (IP) addresses

- → Addresses are always valid - can be hard-coded
- → Addresses refer to services - not locations
- → Address space unique for distributed containers/name spaces

No need to configure L3 networks

- → But VLANS may be useful…

No need to supervise processes or nodes

- → No more heart-beating
- → You will learn about changes - if you want to know

Easy synchronization during start-up

- → First, bind to own service address(es)
- → Second, subscribe for wanted service addresses
- → Third, start communicating when service becomes available

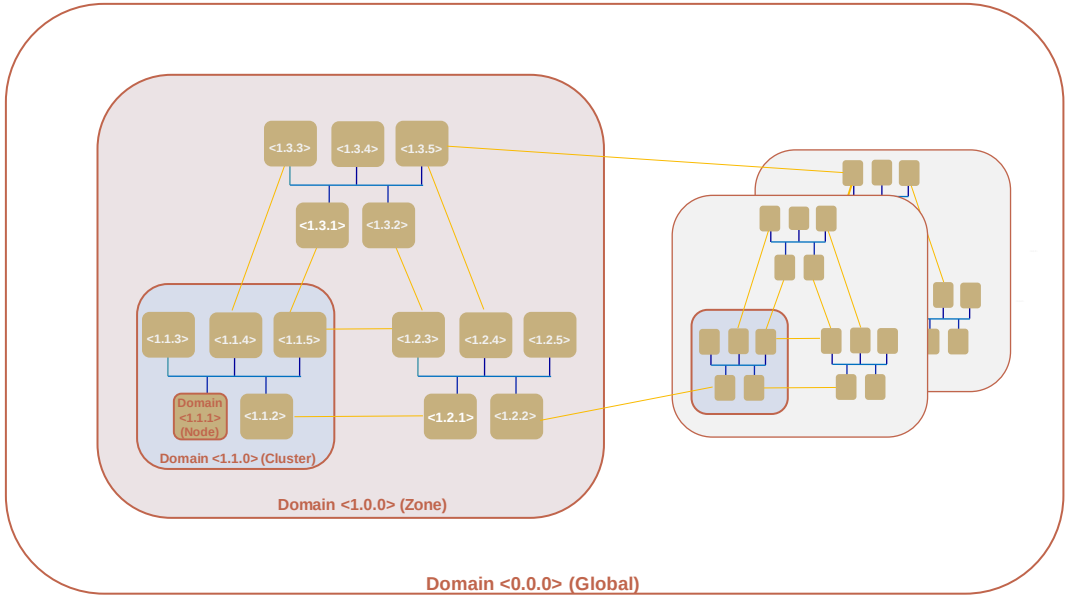
THE DOMAIN CONCEPT

32-bit domain identifier

- → Assigned to node, cluster and zone
- → Structure <Z.C.N> where zero in a position means wildcard (~anywhere/anycast)

```
typedef uint32_t tipc_domain_t;

tipc_domain_t tipc_domain(unsigned int zone,
                          unsigned int cluster,
                          unsigned int node);
```

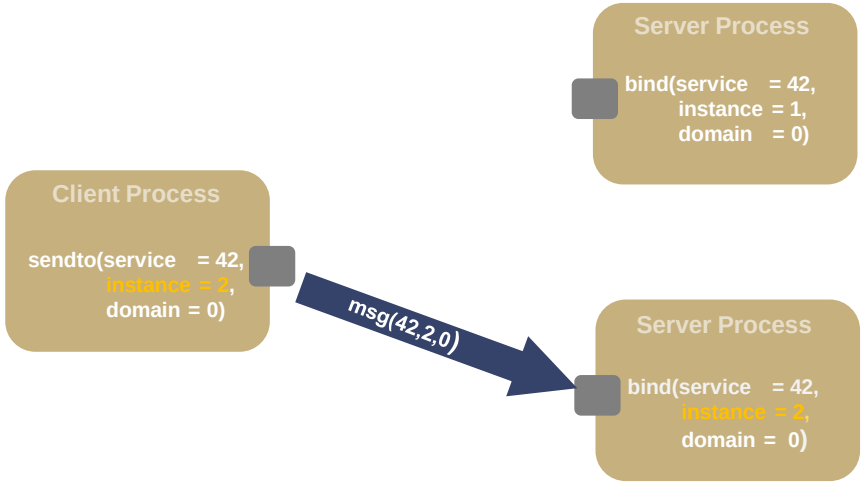


SERVICE ADDRESSING

"Well known port number" assigned by developer

- → **32-bit service type number – typically hard-coded**
- → **32-bit service instance – typically calculated**
- → **32-bit domain identity**
  - → **Indicating visibility scope on the binding side**
  - → **Indicating lookup scope on the calling side**

```
struct tipc_addr{
    uint32_t       type;
    uint32_t       instance;
    tipc_domain_t domain;
};
```

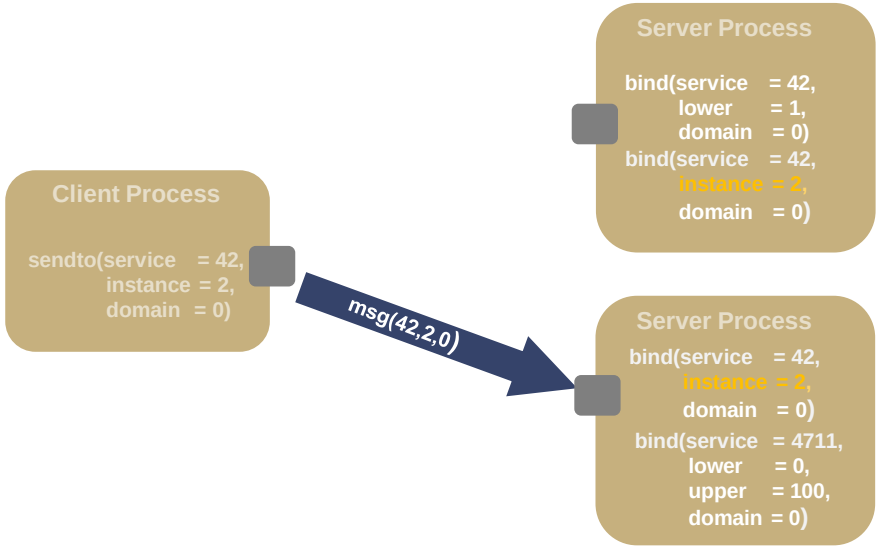


SERVICE BINDING

No (almost) restrictions on how to bind service addresses

- → **Different service addresses can bind to same socket**
- → **Same service address can bind to different sockets**
- → **Ranges of service instances can bind to a socket**

```
struct tipc_addr{
    uint32_t       type;
    uint32_t       instance;
    tipc_domain_t domain;
};
```

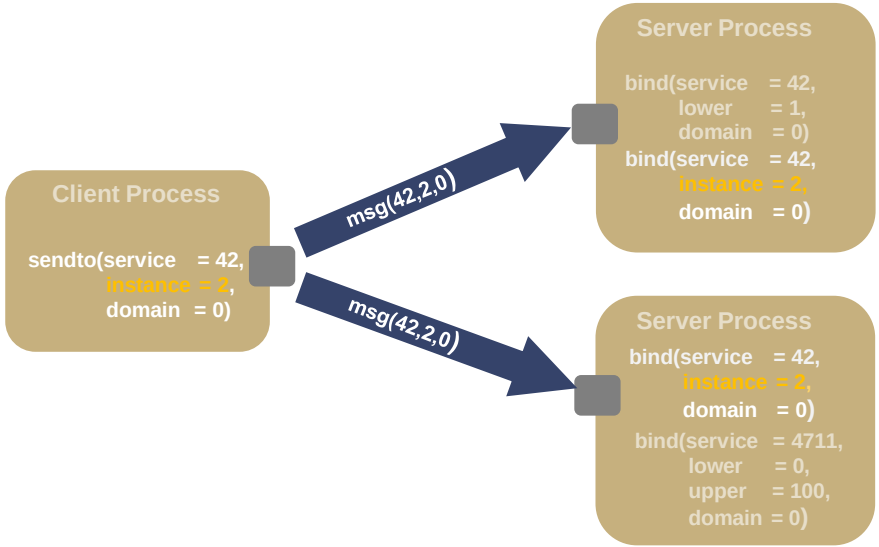


MULTICAST

All servers bound to the given service address receive a copy

→ **Delivery and sequentiality guaranteed socket-to-socket**

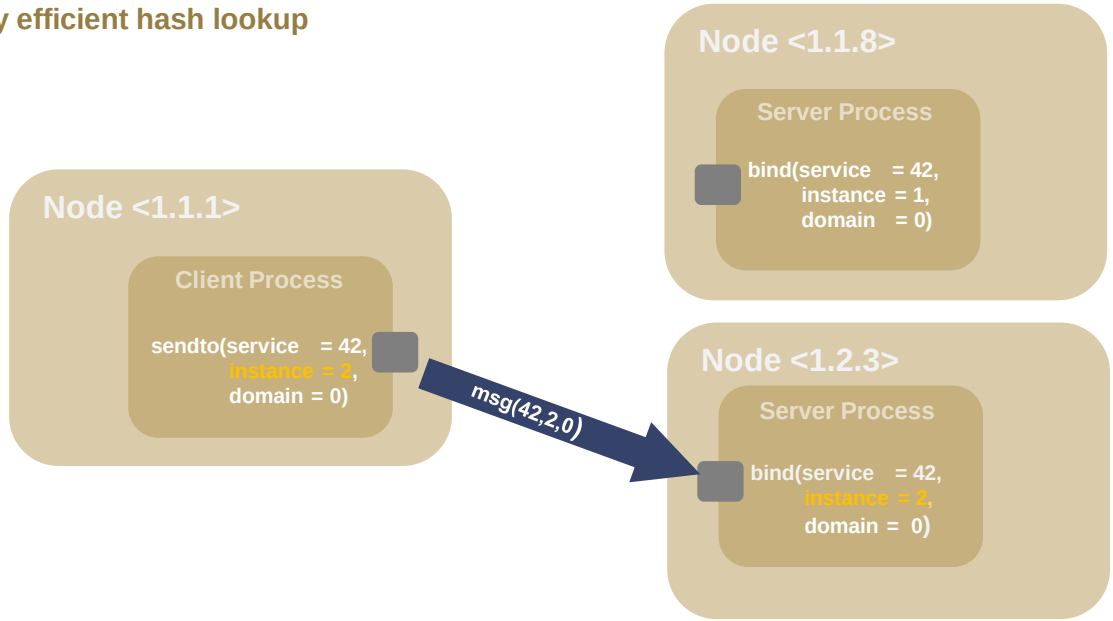
```
struct tipc_addr{
    uint32_t       type;
    uint32_t       instance;
    tipc_domain_t domain;
};
```



LOCATION TRANSPARENCY

Location of server not known by client

- → Translation service address to physical destination performed on-the-fly at source node
- → Replica of global binding table on each node
- → Very efficient hash lookup



RELIABLE DATAGRAM SERVICE

Reliable socket to socket

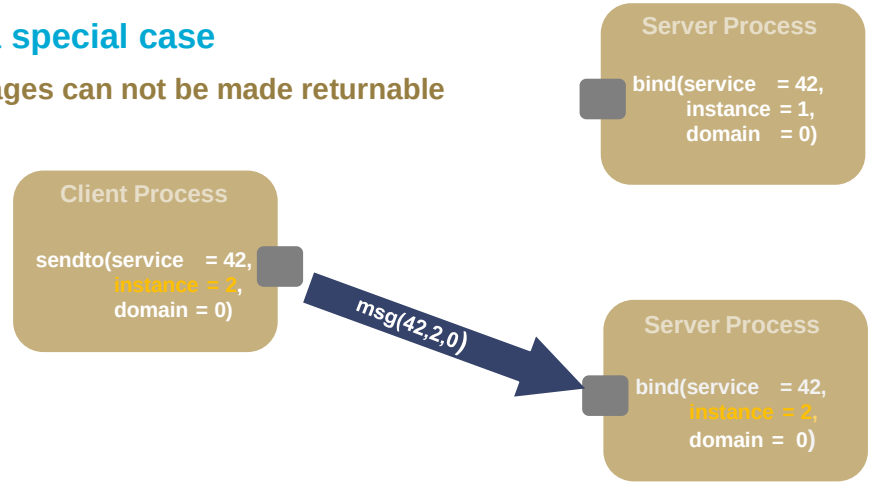
- → Receive buffer overload protection
- → No real flow control, messages may still be rejected

Rejected messages may be dropped or returned

- → Configurable in sending socket
- → Truncated message returned with error code

Multicast is just a special case

- → But messages can not be made returnable



LIGHTWEIGHT CONNECTION

Established by using service address

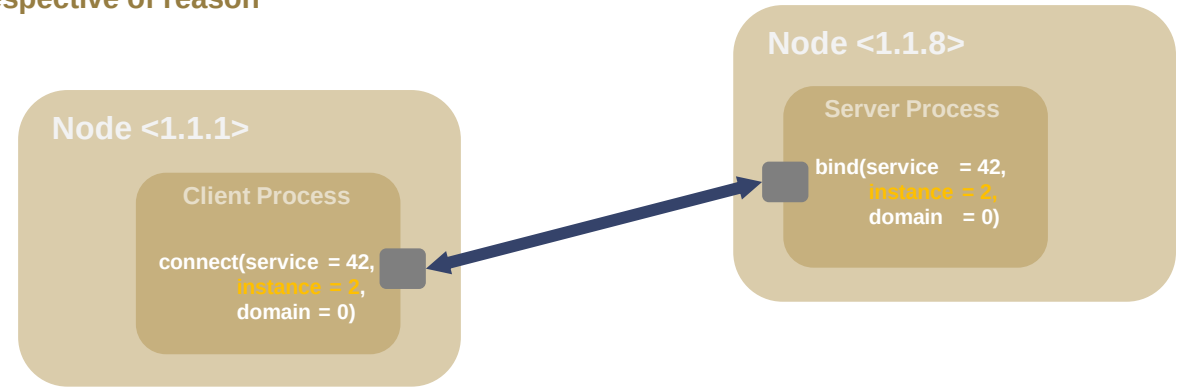
- → Two-way setup using data-carrying messages
- → Traditional TCP-style setup/shutdown also available

Stream- or message oriented

- → End-to-end flow control for buffer overflow protection
- → No sequence numbers, acks or retransmissions, - the link layer takes care of that

Breaks immediately if peer becomes unavailable

- → Irrespective of reason



LINK

"L2.5" reliable link layer, node to node

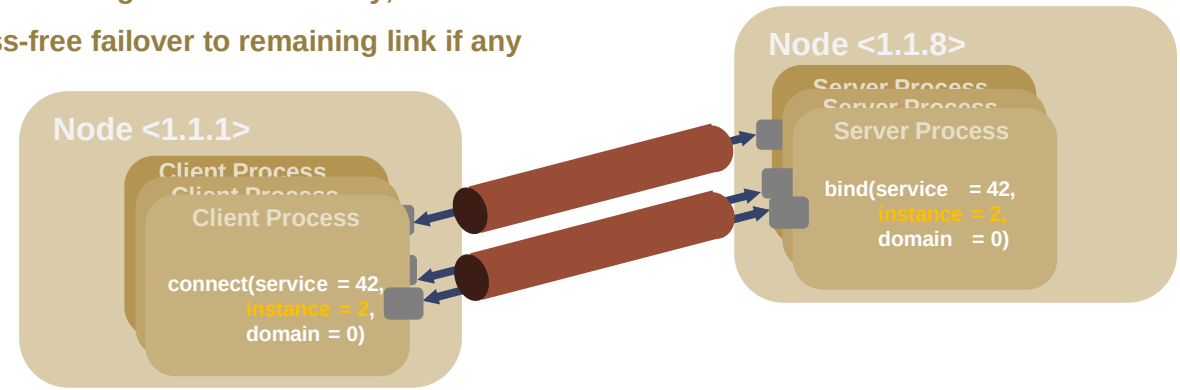
- → Guarantees delivery and sequentiality for all messaging
- → Acts as "trunk" for multiple connections, and keeps track of those
- → Keeps track of peer node's address bindings in local replica of the binding table

Supervised by probing at low traffic

- → "Lost service address" events issued for bindings from peer node if no link left
- → Breaks all connections to peer node if no link left

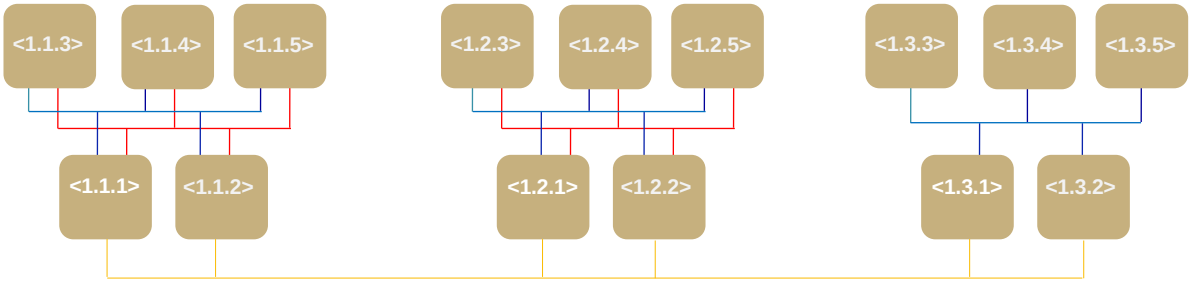
Several links per node pair

- → Load sharing or active-standby, - but maximum two active
- → Loss-free failover to remaining link if any



NEIGHBOR DISCOVERY

- **L2 connectivity determines network**
  - → Neighbor discovery by L2 broadcast, qualified by a lookup domain identity
  - → All qualifying nodes in the same L2 broadcast domain establish mutual links
  - → One link per interface, maximum two active links per node pair
  - → Each node has its own view of its environment



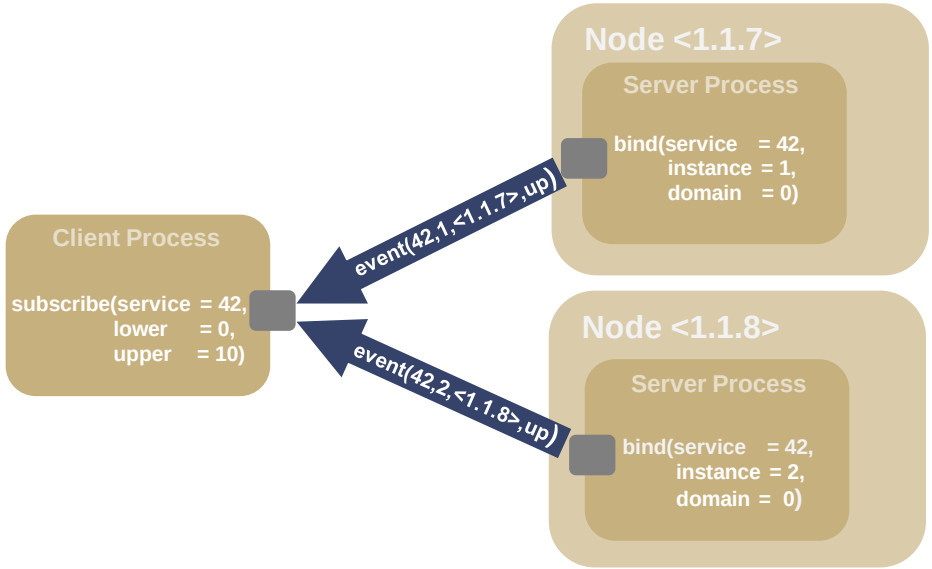
SERVICE SUBSCRIPTION

Users can subscribe for contents of the global address binding table

→ **Receives events at each change matching the subscription**

There is a match when

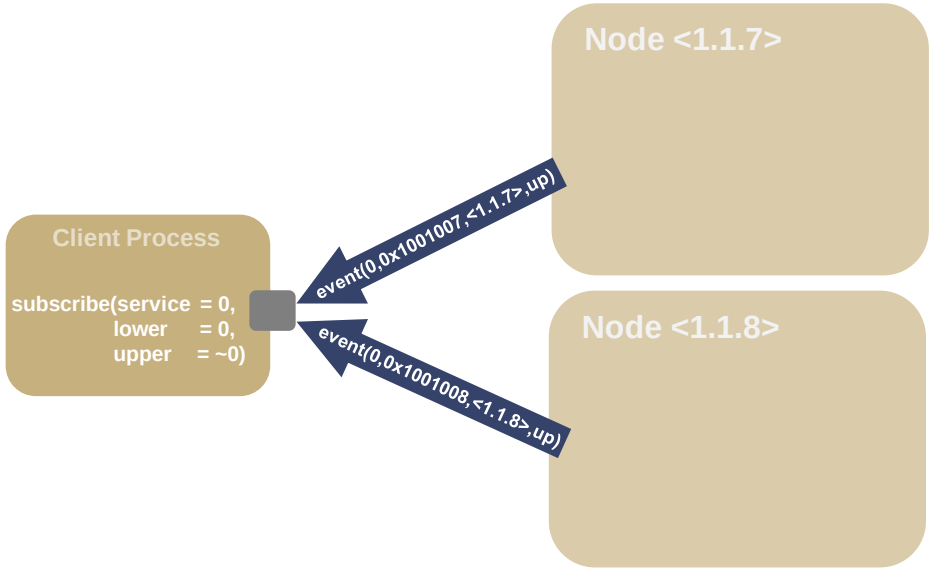
→ **Bound/unbound instance or range overlaps with subscribed range**



TOPOLOGY SUBSCRIPTION

Special case of service subscription

- → Using same mechanism, - based on service table contents
- → Represented by the built-in service type zero (0 ~ “node availability”)



WHEN TO USE TIPC

TIPC does not replace IP based transport protocols

- → It is a complement to be used under certain conditions
- → It is an IPC!

TIPC may be a good option if you

- → Want startup synchronization for free
- → Have application components that need to keep continuous watch on each other
- → Need short latency times
- → Traffic is heavily intra node
- → Don’t want to bother with configuration
- → One L2 hop is enough between your components
- → Are inside a security perimeter

WHAT TIPC WILL NOT DO FOR YOU

No user-to-user acknowledging of messages

- → Only socket-to-socket delivery guaranteed
- → What if the user doesn't process the message?
- → On the other hand, which protocol does?

No datagram transmission flow control

- → For unicast, anycast and multicast
- → Must currently be solved by user
- → We are working on the problem…

No routing

- → Only nodes on same L2 network can communicate
- → But a node may attach to several L2 networks

DEMO

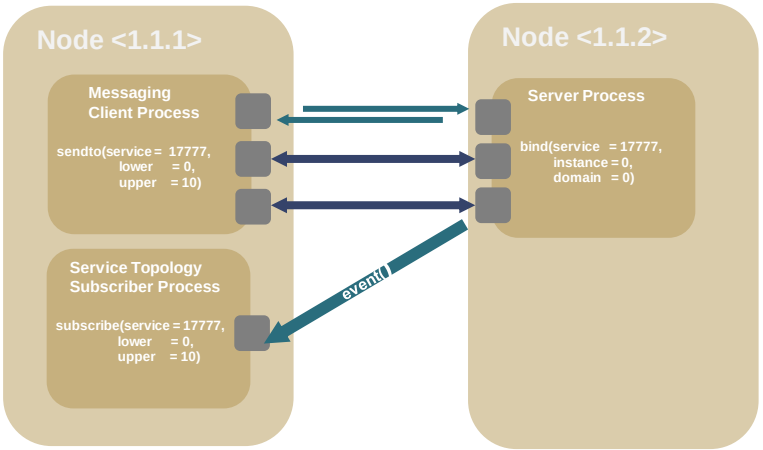
DEMO SETUP

Messaging Client

- → A simple "Hello World" reliable datagram message exchange
- → A "Hello World" message exchange used for a two-way set up a SOCK_STREAM connection
- → A regular TCP-style "connect/accept" to set up a SOCK_SEQPACKET connection

Service Topology Subscriber

- → Subscribing and receiving up/down events for server process availability
- → Subscribing and receiving events about <1.1.1>'s neighbor nodes
- → Remotely subscribing and receiving events about <1.1.2>'s neighbor nodes
- → Subscribing and receiving events for <1.1.1>'s links



STATUS FEBRUARY 2015

FUNCTIONALITY

Only <1.1.N> domains available

- → In reality easy to fix
- → What is the need?

Service binding table still updated by "replicast"

- → Relatively easy to fix, but has not been prioritized
- → It works fine with current cluster sizes

Dropped ambition to have TIPC-level routing between domains

- → Only direct L2 hops is supported
- → IP level routing only option, but still no official L3 bearer
- → UDP based "bearer" implementation soon ready for upstream

Container/Name Space support

- → New as from January 2015

API

Only a low-level socket C API available

- → Hard to learn and use
- → Prototype of a new, higher-level C API available

API for Python, Perl, Ruby, D

- → But not for Java

Support for TIPC in ZeroMQ

- → Not yet with full features

AVAILABILITY

Installation package available only in SLES

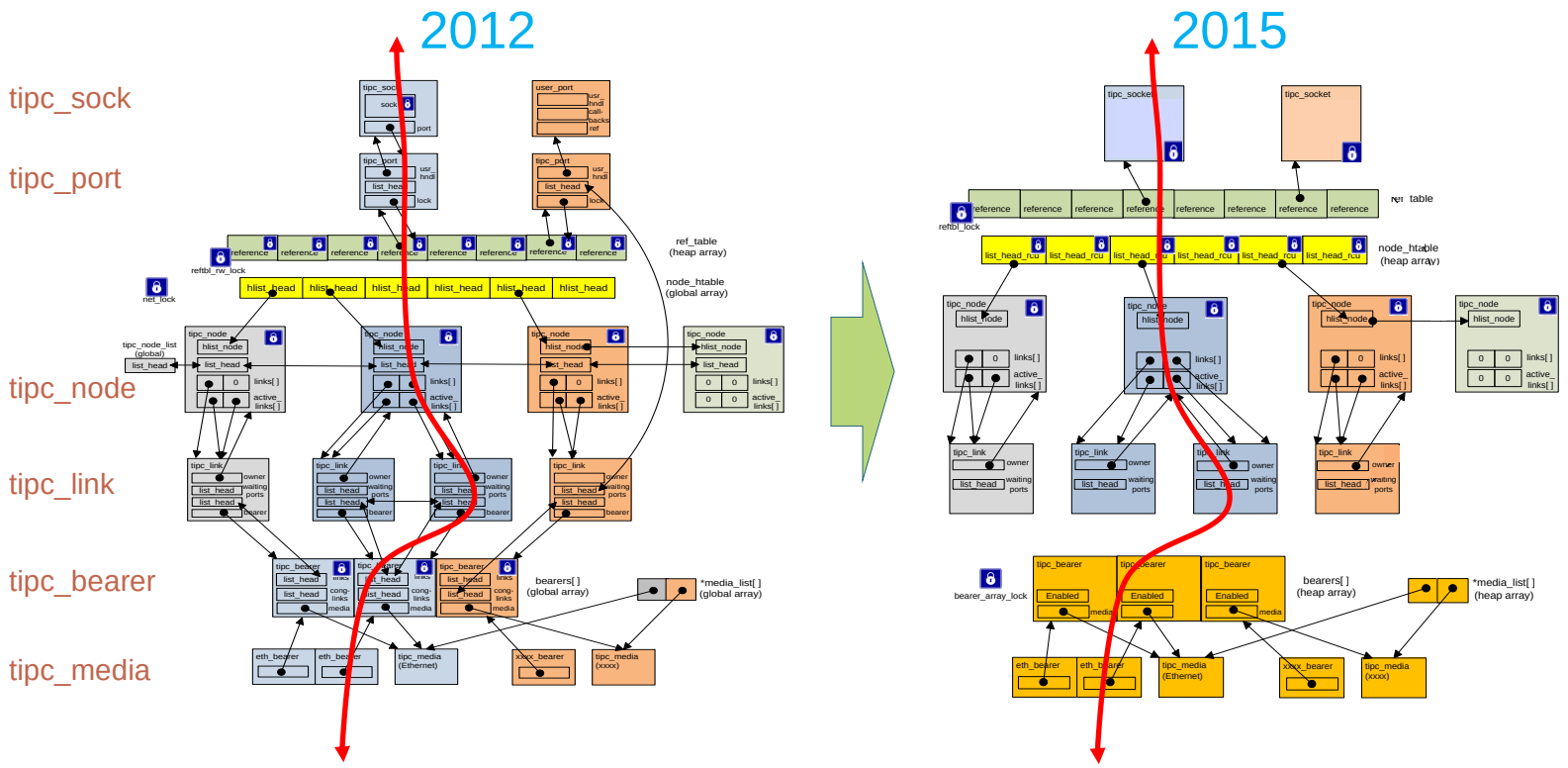
Earlier supported package in Debian/Ubuntu broken

→ **Volunteers wanted**

No package yet in Fedora/RHEL

→ **We are working on this**

ARCHITECTURE



IMPLEMENTATION

Significant effort to improve quality and maintainability the last 2-3 years

- → Eliminated the redundant "native API" and related "port layer"
  - → Only sockets are supported now
- → Reduced code bloat
- → Reduced structure interdependencies
- → Improved locking policies
  - → Fewer locks, RCU locks instead of RW locks…
  - → Eliminated all known risks of deadlock
- → Buffer handling
  - → Much more use of sk_buff lists and other features
  - → Improved and simplified fragmentation/reassembly

Support for name spaces

- → Will be very useful in the cloud
- → Enables "distributed containers"

Linuxification of code and coding style

- → Still too visible that TIPC comes from a different world
- → Adapting to kernel naming conventions

TRAFFIC CONTROL

Connection flow control is still message based

- → May potentially consume enormous amounts of memory
- → skb_truesize() in combination with out no-drop requirement is a problem
- → We think we have a solution

Link flow control still uses a fix window

- → Too simplistic
  - → We need a congestion avoidance algorithm
- → Lots of unnecessary retransmits

Datagram flow control missing

- → Probably impossible to get this hundred percent safe
  - → But we can make it much better than now

SCALABILITY

Largest known cluster we have seen is 72 nodes

- → Works flawlessly
- → We need to get up to hundreds of nodes
- → The link supervision scheme may become a problem

Limited domain support

- → We need support for <Z.C.N>, not only <1.1.N>
- → Makes it possible to segment TIPC networks

Name space support

- → DONE!!!

PERFORMANCE

Latency times better than on TCP

- → 10-20% inter-node
- → 2 to 7 times faster intra-node messaging (depends on message size)
  - → We don't use the loopback interface

Throughput still poorer than TCP

- → 55-100 % of max TCP throughput inter-node
  - → Seems to be very environment dependent
- → But 25-30% better than TCP intra-node

MANAGEMENT

New netlink based API introduced

- → Replaces old ascii-based commands (also via netlink)
- → Uses more standard features such as socket buffers, attribute nesting, sanity checks etc.
- → Scales much better when clusters grow

New user space tool "tipc"

- → Syntax inspired by "ip" tool
- → Modular design inspired by git
- → Uses libnl
- → Replaces old "tipc-config" tool
- → Part of tipc-utils package

ROADMAP 2015-2016

FUNCTIONALITY

Allowing overlapping address ranges for same type

- → Currently only limitation to service binding
- → Causes race problems sometimes
- → Proposal exists

Updating binding table by broadcast instead of replicast

- → We know how to do this
- → Compatibility biggest challenge

LIBTIPC WITH C API

Addressing in TIPC socket API

```
struct tipc_portid {
        __u32 ref;
        __u32 node;
};
struct tipc_name {
        __u32 type;
        __u32 instance;
};
struct tipc_name_seq {
        __u32 type;
        __u32 lower;
        __u32 upper;
};

#define TIPC_ADDR_NAMESEQ       1
#define TIPC_ADDR_MCAST         1
#define TIPC_ADDR_NAME          2
#define TIPC_ADDR_ID            3

struct sockaddr_tipc {
        unsigned short family;
        unsigned char  addrtype;
        signed   char  scope;
        union {
                struct tipc_portid id;
                struct tipc_name_seq nameseq;
                struct {
                        struct tipc_name name;
                        __u32 domain; /* 0: own zone */
                } name;
           } addr;
};
```

Addressing in TIPC C API

```
typedef uint32_t tipc_domain_t;

struct tipc_addr {
        uint32_t      type;
        uint32_t      instance;
        tipc_domain_t domain;
};
```

Service/topology subscriptions in C API

```
int tipc_topsrv_conn(tipc_domain_t topsrv_node);
int tipc_srv_subscr(int sd, uint32_t type, uint32_t lower, uint32_t upper,
                    bool all, int expire);
int tipc_srv_evt(int sd, struct tipc_addr *srv, bool *available, bool expired);
bool tipc_srv_wait(const struct tipc_addr *srv, int expire);

int tipc_neigh_subscr(tipc_domain_t topsrv_node);
int tipc_neigh_evt(int sd, tipc_domain_t *neigh_node, bool *available);
```

http://sourceforge.net/p/tipc/tipcutils/ci/master/tree/demos/c_api_demo/tipcc.h

TRAFFIC CONTROL

Improved connection level flow control

- → Packet based instead of message based
- → Byte based does not seem feasible

Improved link level flow control

- → Adaptable window size
- → Congestion avoidance
- → SACK, FRTO …?

Datagram and multicast congestion feedback

- → Sender socket selects least loaded destination
- → Sender socket bocks or returns –EAGAIN if all destinations congested
- → Academic work ongoing to find best algorithm

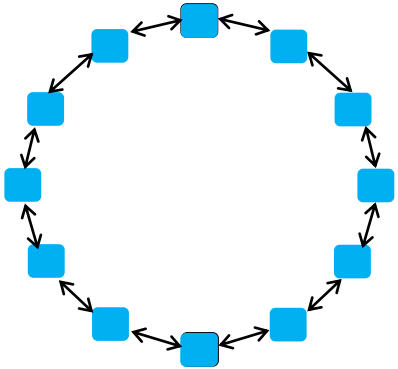
SCALABILITY

Full network address space

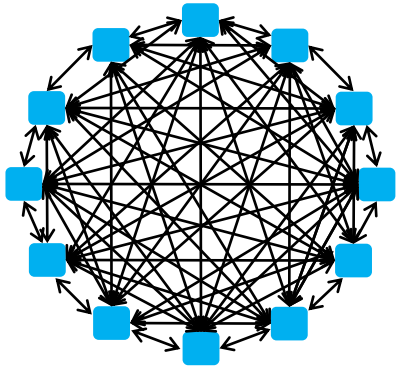
- → Node identity <Z.C.N> instead of <1.1.N>
- → Can group nodes by discovery rules instead of VLANS

Hierarchical neighbor supervision and failure detection

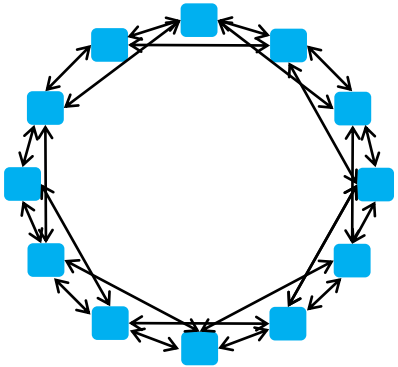
- → "Biased Gossip" type algorithm ?



Ring: Scales ~2*N



TIPC: Scales ~N*(N-1)



TIPC/Gossip: Scales ~M*N

PERFORMANCE

Improved link level flow control

- → Already mentioned

Separate spinlock for each parallel link to same node

- → Currently jointly covered by a "node_lock", serializing access
- → Loss-free transitions 1-2 and 2-1 (failover) links will be a challenge

Reducing and fragmenting code sequences covered by node_lock (link_lock)

- → Gives better parallelization
- → Big potential for improvements

Dualpath connections

- → 20 Gb/s per connection?

General code optimization

- → Based on profiling

MULTICAST/BROADCAST

Code overhaul of broadcast link

- → Leveraging recent changes to unicast link

Multicast groups

- → Explicit membership handling

Transactions

- → Ensure "all-or-nothing" delivery

Virtual Synchronism

- → Ensure virtual in-order delivery
- → From different source nodes

MORE INFORMATION

TIPC project page

http://tipc.sourceforge.net/

TIPC protocol specification

http://tipc.sourceforge.net/doc/draft-spec-tipc-10.html

TIPC programmer's guide

http://tipc.sourceforge.net/doc/tipc_2.0_prog_guide.html

TIPC C API

http://sourceforge.net/p/tipc/tipcutils/ci/master/tree/demos/c_api_demo/tipcc.h

THANK YOU

INTER-NODE THROUGHPUT (NETPERF)

```
Intel(R) Xeon(R) CPU E5-2658 v2 @ 2.40GHz 48G ECC ram
3.19 RC4+ kernel + busybox. No tuning done.
Netperf stream test, ixgbe NIC's, TCP using cubic, TIPC link window=400.


TCP:
MIGRATED TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to 11.0.0.3 () port 0 AF_INET
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    60.00    8338.82

TIPC:
TIPC STREAM TEST to <1.1.3:3089135711>
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

34120200 212992 212992    60.00    4351.60
```

INTER-NODE THROUGPUT (TIPC TOOL)

```
blade3 ~ # ./client_tipc -p tcp -i eth4
****** TIPC Benchmark Client Started ******

Transferring 64000 messages in TCP Throughput Benchmark
+-------------------------------------------------------------------------------+
|  Msg Size  | #     |  # Msgs/  |  Elapsed  |                Throughput              |
|  [octets]  | Conns |    Conn   |  [ms]     +----------------------------------------+
|            |       |           |           | Total [Msg/s] | Total [Mb/s] | Per Conn [Mb/s] |
+-------------------------------------------------------------------------------+
|        64  |    1  |    64000  |      115  |       552409  |         282  |            282  |
+-------------------------------------------------------------------------------+
|       256  |    1  |    32000  |       60  |       526099  |        1077  |           1077  |
+-------------------------------------------------------------------------------+
|      1024  |    1  |    16000  |       54  |       292029  |        2392  |           2392  |
+-------------------------------------------------------------------------------+
|      4096  |    1  |     8000  |       85  |        93857  |        3075  |           3075  |
+-------------------------------------------------------------------------------+
|     16384  |    1  |     4000  |      209  |        19134  |        2507  |           2507  |
+-------------------------------------------------------------------------------+
|     65536  |    1  |     2000  |      248  |         8032  |        4211  |           4211  |
+-------------------------------------------------------------------------------+
Completed Throughput Benchmark
****** TIPC Benchmark Client Finished ******
```

TCP Inter Node

```
blade3 ~ # ./client_tipc
****** TIPC Benchmark Client Started

Transferring 64000 messages in TIPC Throughput Benchmark
+-------------------------------------------------------------------------------+
|  Msg Size  | #     |  # Msgs/  |  Elapsed  |                Throughput              |
|  [octets]  | Conns |    Conn   |  [ms]     +----------------------------------------+
|            |       |           |           | Total [Msg/s] | Total [Mb/s] | Per Conn [Mb/s] |
+-------------------------------------------------------------------------------+
|        64  |    1  |    64000  |      304  |       209847  |         107  |            107  |
+-------------------------------------------------------------------------------+
|       256  |    1  |    32000  |      164  |       194584  |         398  |            398  |
+-------------------------------------------------------------------------------+
|      1024  |    1  |    16000  |      104  |       153283  |        1255  |           1255  |
+-------------------------------------------------------------------------------+
|      4096  |    1  |     8000  |       86  |        92803  |        3040  |           3040  |
+-------------------------------------------------------------------------------+
|     16384  |    1  |     4000  |      147  |        27196  |        3564  |           3564  |
+-------------------------------------------------------------------------------+
|     65536  |    1  |     2000  |      249  |         8027  |        4208  |           4208  |
+-------------------------------------------------------------------------------+
Completed Throughput Benchmark
****** TIPC Benchmark Client Finished ******
```

TIPC Inter Node

LATENCY (TIPC TOOL)

TCP Inter Node

```
blade3 ~ # ./client_tipc -p tcp -i eth4
****** TIPC Benchmark Client Started ******
+-----------------------------------------------------------------------+
| Msg Size [octets] |   # Msgs   | Elapsed [ms] | Avg round-trip [us] |
+-----------------------------------------------------------------------+
|                64 |      8000 |          341 |                42.2 |
+-----------------------------------------------------------------------+
|               256 |      4000 |          232 |                58.0 |
+-----------------------------------------------------------------------+
|              1024 |      2666 |          145 |                54.39 |
+-----------------------------------------------------------------------+
|              4096 |      2000 |          497 |              248.86 |
+-----------------------------------------------------------------------+
|             16384 |      1600 |          399 |              249.15 |
+-----------------------------------------------------------------------+
|             65536 |      1333 |          665 |              499.13 |
+-----------------------------------------------------------------------+
Completed Latency Benchmark
Transferring 64000 messages in TCP Throughput Benchmark
```

TCP Intra Node

```
root@tipc1:~# bmc -p tcp
****** TIPC Benchmark Client Started ******
Using server address 127.0.0.1:4711
Transferring 80000 messages in TCP Latency Benchmark
+-----------------------------------------------------------------------+
| Msg Size [octets] |   # Msgs   | Elapsed [ms] | Avg round-trip [us] |
+-----------------------------------------------------------------------+
|                64 |     80000 |          823 |                10.94 |
+-----------------------------------------------------------------------+
|               256 |     40000 |          445 |                11.36 |
+-----------------------------------------------------------------------+
|              1024 |     26666 |         1041 |                39.64 |
+-----------------------------------------------------------------------+
|              4096 |     20000 |          884 |                44.20 |
+-----------------------------------------------------------------------+
|             16384 |     16000 |         1443 |                90.35 |
+-----------------------------------------------------------------------+
|             65536 |     13333 |         1833 |              137.5  |
+-----------------------------------------------------------------------+
Completed Latency Benchmark
```

TIPC Inter Node

```
blade3 ~ # ./client_tipc
****** TIPC Benchmark Client Started ******
+-----------------------------------------------------------------------+
| Msg Size [octets] |   # Msgs   | Elapsed [ms] | Avg round-trip [us] |
+-----------------------------------------------------------------------+
|                64 |      8000 |          311 |                38.65 |
+-----------------------------------------------------------------------+
|               256 |      4000 |          209 |                52.78 |
+-----------------------------------------------------------------------+
|              1024 |      2666 |          228 |                85.51 |
+-----------------------------------------------------------------------+
|              4096 |      2000 |          249 |              124.84 |
+-----------------------------------------------------------------------+
|             16384 |      1600 |          258 |              161.65 |
+-----------------------------------------------------------------------+
|             65536 |      1333 |          652 |              489.58 |
+-----------------------------------------------------------------------+
Completed Latency Benchmark
****** TIPC Benchmark Client Finished ******
```

TIPC Intra Node

```
root@tipc1:~# bmc
****** TIPC Benchmark Client Started ******
Transferring 80000 messages in TIPC Latency Benchmark
+-----------------------------------------------------------------------+
| Msg Size [octets] |   # Msgs   | Elapsed [ms] | Avg round-trip [us] |
+-----------------------------------------------------------------------+
|                64 |     80000 |          426 |                5.34  |
+-----------------------------------------------------------------------+
|               256 |     40000 |          219 |                5.90  |
+-----------------------------------------------------------------------+
|              1024 |     26666 |          141 |                5.12  |
+-----------------------------------------------------------------------+
|              4096 |     20000 |          121 |                6.81  |
+-----------------------------------------------------------------------+
|             16384 |     16000 |          186 |                11.36 |
+-----------------------------------------------------------------------+
|             65536 |     13333 |          328 |                24.50 |
+-----------------------------------------------------------------------+
Completed Latency Benchmark
```