Active Networking and the End-to-End Argument

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Outline

- Active networking
- The end-to-end argument
- Modeling service placement
- Reliable Multicast
- Summary

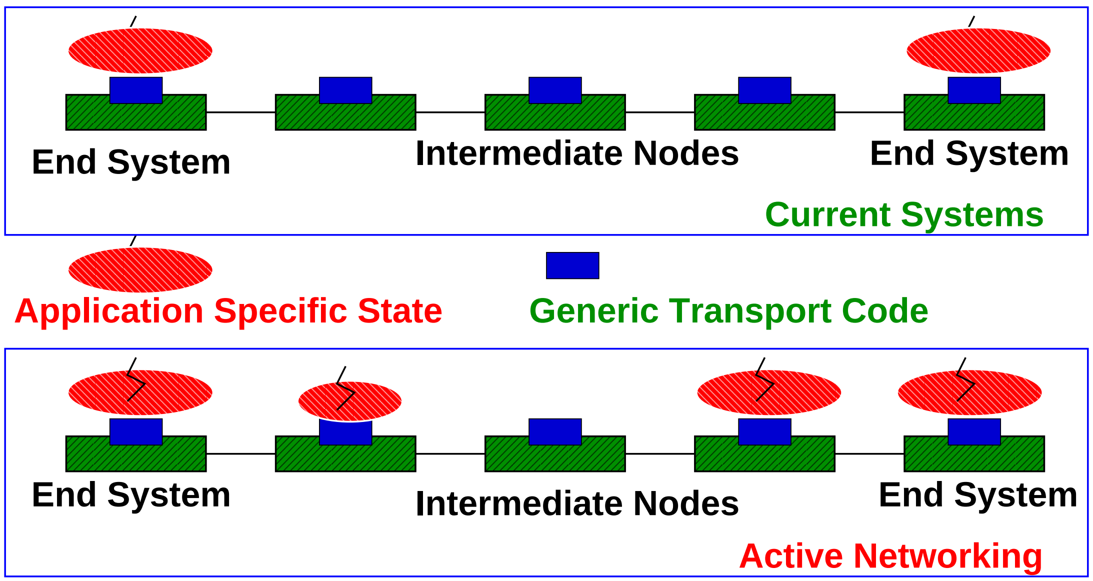
Active Networking

Active networking is...

- The placement of user-controllable computing capabilities inside the communication subnetwork.
- Providing a meta-level interface to the network.
- *Active* capabilities:
  - Transport of code to be executed at intermediate nodes
    * Reliable Multicast
    * Application-specific congestion control
    * Application-specific caching

Active Networking in a Distributed System

In general, active networking allows state sharing within *all* nodes in a distributed system.



Placement and manipulation of application-specific state within the communication subnetwork.

What about the End-to-End Argument?

> "...provides a rationale for moving a function upward in a layered system closer to the application that uses the function."

(Saltzer, Reed, and Clark, ACM ToCS, 1984.)

- Distributed system provides some functions — like reliable data transfer.
- Functions may be implemented by the communication subsystem, by the end-systems, jointly, or redundantly.

E2E Argument

- Application requirements dictate functions can *completely and correctly* be implemented *only with the knowledge of the application*.
- Providing such *functions as an implicit feature of the communication subsystem* is not possible, or very expensive.
- Fundamental engineering tradeoff in placement of functions within the system.

AN and the E2E Argument

Active networking is consistent with the end-to-end argument

A properly designed active network:

- Provides a generic interface, available to all users.
- The interface allows users to more precisely select the services they need.
- The cost of the interface is a one-time cost (infrastructure).
- The cost of providing a service is paid only by those applications using it.

Active networking allows the system designer to *choose* to implement functionality within the network.

A Model for Service Location

- Quantification of the engineering trade-off
- Analyze expected performance under two design options —
  - **Design X:** Service implementation exclusive in the end-systems
  - **Design C:** Service achieved through combination of implementation at the end-systems and in the network
- Assumption: Network support for service is boolean.

Model Development

Exclusively End-system (Design X)

T_X	Expected performance

Combined End-system and Network (Design C)

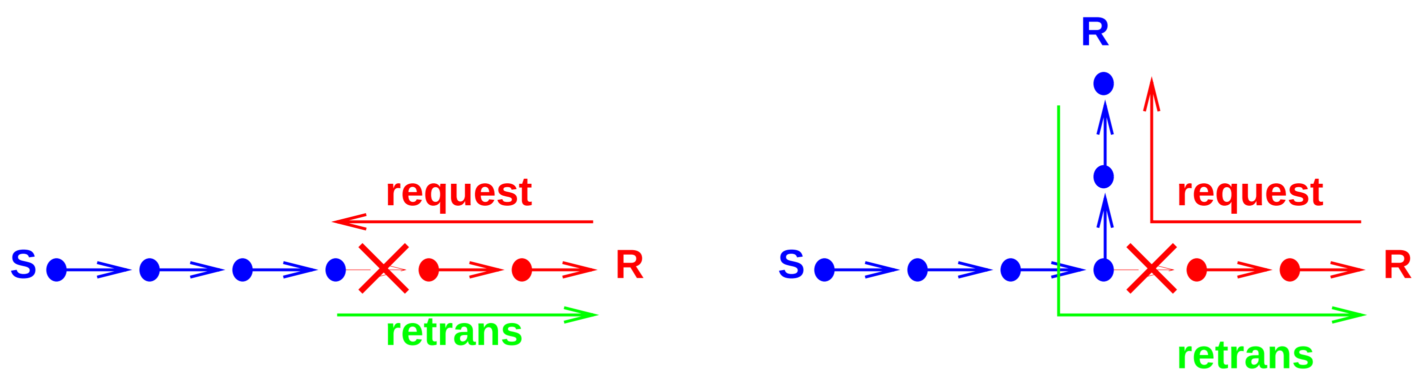
T_C	Expected performance
p_n	Pr{network support accomplishes service}
T_E	Expected performance, end-system version
T_N	Expected performance, network version

Thus,

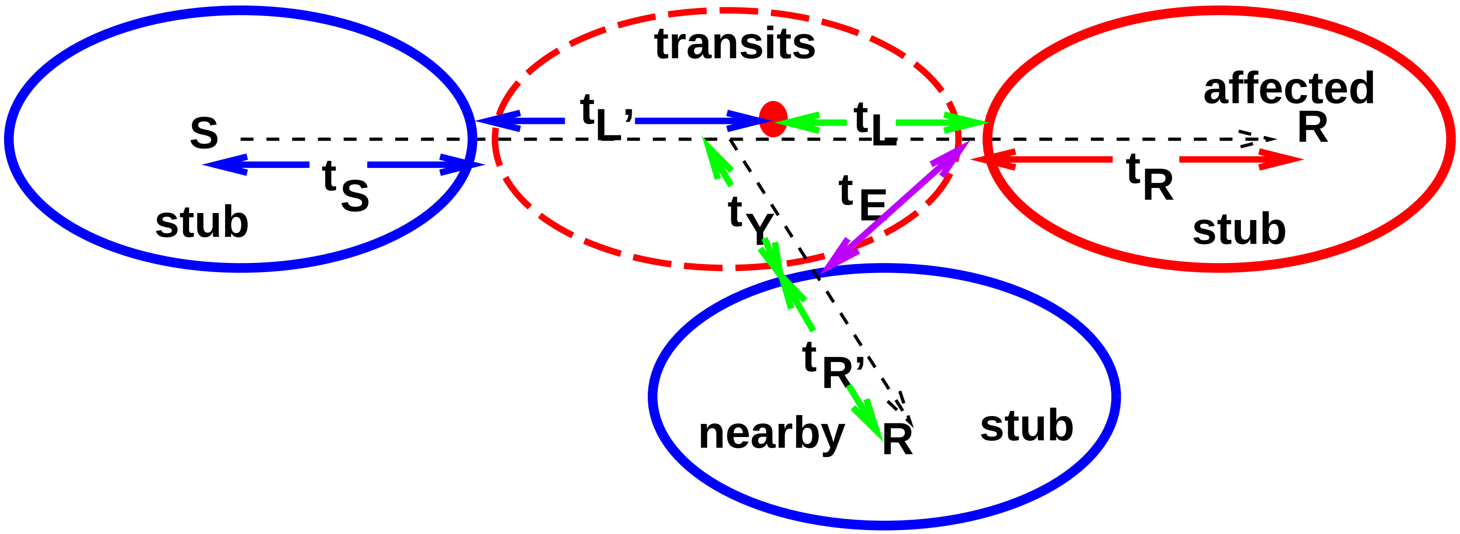
$$T_C = (1 - p_n)T_E + p_n T_N$$

Reliable Multicast

- Provide reliability for multicast flows using active networking
- Main Idea : Active nodes on path can cache multicast packets, and retransmit them upon detection of loss.



Modeling Reliable Multicast



assume $t_R = t_{R'} = t_S$ and $t_L = t_{L'}$

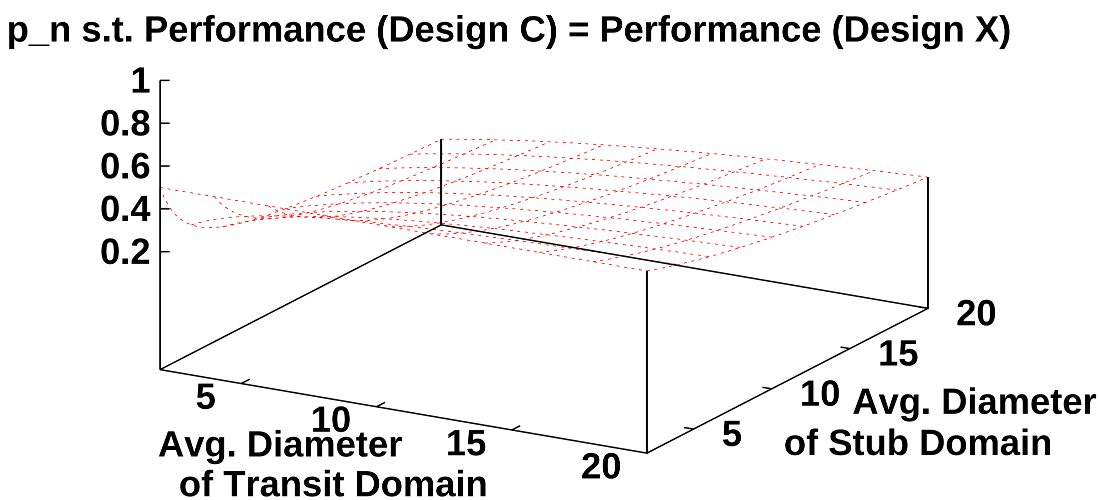
$$
\begin{aligned}
T_X &= t_R + t_L + t_Y + 2t_R + t_E + t_R \\
&= 4t_R + (t_L + t_Y + t_E) \\
T_C &= p_n 2(t_R + t_L + 1) + (1 - p_n)2(t_R + 2t_L + t_R) \\
&= 4t_R + 4t_L - 2p_n(t_R + t_L - 1)
\end{aligned}
$$

Reliable Multicast: Analysis

Thus, to achieve $T_C < T_X$:

$$p_n > \frac{3t_L - t_Y - t_E}{2(t_R + t_L - 1)}$$

Assuming $t_E = t_Y = t_L$:



Summary

- Active networking is consistent with the end-to-end argument.
- Active networking provides more options for function placement is a distributed system.
- Performance of current systems/protocols may be improved using active networking, and not violate the end-to-end argument.