The End-to-end Argument

- = inside the network (in switching elements), or encryption, reliability, ordering, duplication surpression): Deals with where to place protocol functionality (e.g.,
- other architecture can use this principle Mot an arhchitecture in itself, but an architectural principle
- e.g., architectures for transaction management



[Saltzer81a] End to End Argument **C2221**

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http://merlot.usc.edu/cs551-f12

Example: Reliability

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- Consider copying a file
- reliable delivery - want an end-to-end checksum, even if network guarantees
- :sqət2 🔷
- A reads from disk to memory; sends over network
- a of A morts data from A to B
- B gets data from network; writes to disk
- network corruption or congestion, computer crashes disk I/O errors, buffer overruns in MIC, memory errors, :etlust əldiseo9 🔷
- end-to-end reliable guarantee (and not rely on the data application program must supply a file-transfer-specific, Recommendation: in order to achieve reliable file transfer,

communication system)

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The end-to-end argument

- have to do it at the top anyway adon't duplicate functionality in multiple levels if you
- apply to networking: the lower layers of the network are

Key Ideas

- functions (the lower network layers should implement not the right place to implement application-specific
- o move these functions up and out basic and general functions)
- the network should be as transparent as technology
- Duplicate functionality has a cost associated with it
- Meed to be general: Additional functionality may help - better spend it on other things

some but may actually hurt other applications

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Encrypted data transfer (cannot trust the network)

Duplicate message suppression (did I just double-click the

Other Examples

button or single-clicked it?)

Guaranteed FIFO message delivery

Transactions in a DB

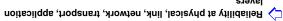
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Caveat: Performance

Consider file copy again



- need some physical redundancy (coding)
- = sometimes want link repair (Ethernet retransmission after
- network level repair (TCP) collision, wireless links)
- application level checks (checksum)
- correctness multiple levels may be needed for performance, not

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Difficulty: What Is the "End"?

- Consider secure communication:

 me to my bank over HTTPS: browser to commerce server
- = me from home to USC over ssh: app-level
- my computer to USC over a virtual private network (VPN): network-layer on my computer to USC network
- my computer to the wireless base-station over 802.11 with WEP: link-layer on my computer to wireless LAM
- = my PIN number in my head to the ATM (?)
- Lower-layers have benefits (wider coverage)

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- End-to-end argument is not an absolute rule (like Occam's razor)

 rather a quideline that helps in application and protocol
- e rather a guideline that helps in application and protocol design analysis

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End2End: A Broader View

What breaks end2end connectivity?

so deW =

Transparent web proxies

- Others?

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- NAT - who's talking? - Web caches - web page out of date, server wants to keep -

a hit count — Transparent web proxies - where are the ads? what else

is filtered out?

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have to be duplicated at the ends anyway

Context — came well b

Cummary 🖒

= came well before much of the Internet had been built

Discussion

networking — measure of worth: not many papers are remembered after 20 years

helpful for understanding the success of the Internet
 people tend to use it to justify/dispute everything

o active networks, sensor networks, etc.

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