Optimization and Control of Networks

Architectural Principles of the Internet

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The Internet Protocol Stack

- TCP/IP was first proposed in 1973
- The specifications are well-known, but the motivation/reasoning behind is not
- The design philosophy has evolved considerably
  - Connectionless services
  - The layering into the IP and TCP layers
- The Internet architecture is still evolving
  - Mainly driven by physical technologies and applications
  - Clean-slate Internet design

The design goals

- (0) The top level goal is to connect existing networks
  - Was originally connect ARPANET with the ARPA packet radio network
  - Was assumed there would be other sorts of networks
- (1) Survivability in the face of failure
  - Should continue to provide communications service, even though networks and components are failing
- (2) To support multiple types of services
  - Different types are differentiated by QoS requirements in throughput, delay, and reliability
  - Mostly provides best-effort services

The design goals

- (3) To accommodate a variety of physical networks
  - Important for the success of the Internet architecture
  - Has been successfully met
- (4) To allow distributed management
  - The internet is a federated network of autonomous systems
  - Lack sufficient tools, and usually requires manual configuration and is error-prone
- (5) To be cost effective
  - It is not very, as the Internet is a general purpose network
  - Lots of overhead, retransmission of lost packet

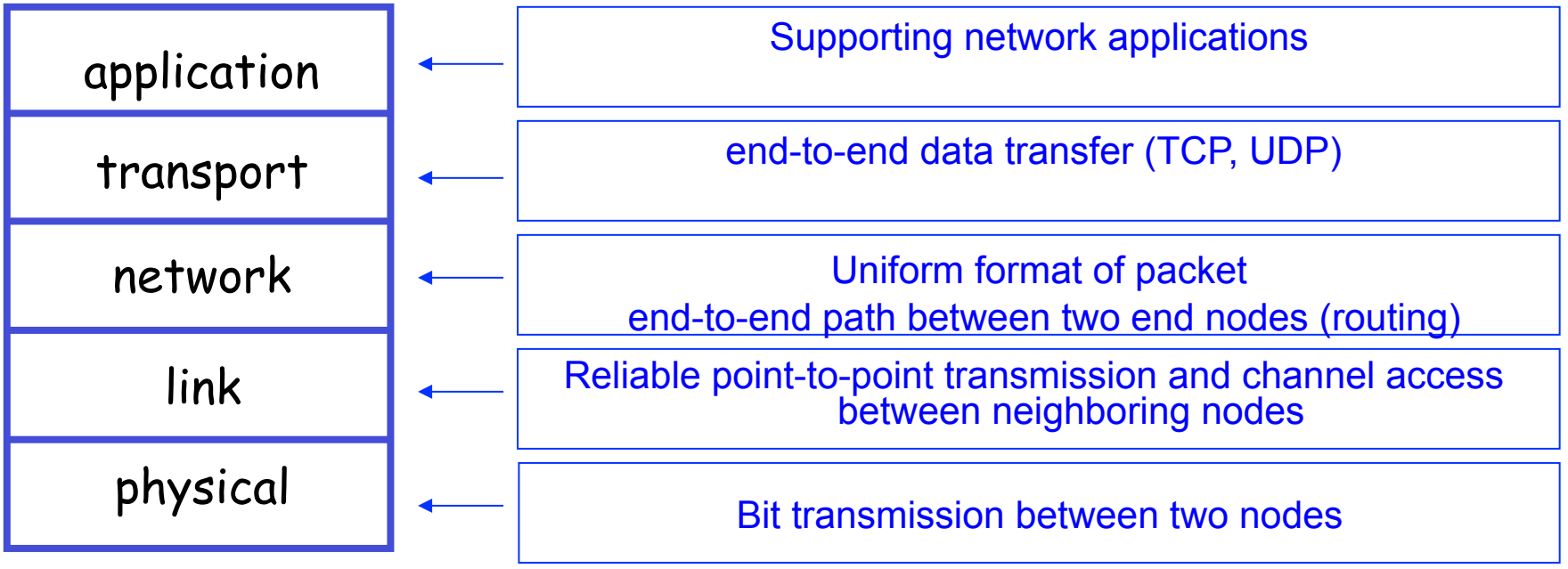
The design goals

- (6) To allow host attachment with a low level of effort
- (7) To allow accountability
  - Was discussed in the first proposal
  - But mostly not met
  - well-provisioning covers the issue

The design principles

- Layering
- Packet switching
- A network of collaborating networks
- Intelligent end-systems
- End-to-end argument

Layering


application
transport
network
link
physical
Supporting network applications
end-to-end data transfer (TCP, UDP)
Uniform format of packet
end-to-end path between two end nodes (routing)
Reliable point-to-point transmission and channel access between neighboring nodes
Bit transmission between two nodes

Layering

- Each layer offers a service to the next layer above, and implements this service using the services offered by the layer below
  - Offers reduction in complexity
  - Isolation of functionality
  - A way to structure the network protocol designs
- The thin waist – the network layer
  - Almost any network provides the service required by the network layer: to deliver packets between neighboring nodes
  - Enables simple interconnection of existing networks (design goal 0)
  - Enables the accommodation of a variety of networks (design goal 3)

Packet switching

- Packet switching
  - Data has to be split into packets
  - Packets carry destination address and traverse the network independently
  - High efficient because of statistical multiplexing
  - Packets may get dropped (best effort service)
- Allows the use of a stateless routing system at the network layer, which does not require per connection state
  - Ensure scalability and contributes to cost effectiveness (design goal 5)
  - Help with survivability (design goal 1)

Network of Collaborating networks

- The Internet is a federated network of autonomous systems
  - Collaborate to provide connectivity
  - Intradomain routing
  - interdomain routing (policy based)
  - Decide the next hop based on information from neighboring nodes
- Ensure suuvivability (design goal 1)
- Allow distributed management (design goal 5)

Intelligent end systems / the end to end argument

- Keep the network dumb and place intelligent at the end system
  - The network layer can drop packets
  - The end-systems are responsible for reliability
- End to end argument is about placing functionality: Place inside the network rather than end-systems, if
  - All applications need it, or a large number of applications benefit from an increase in performance
  - Reliability is not
- Help ensure survivability (design goal 1) and cost effectiveness (design goal 5)

A few comments

- The internet fulfills most of original design goals 0-5
  - The network layer can drop packets
  - The end-systems are responsible for reliability
- Other add-ons
  - Dynamic Host Configuration Protocol (DHCP) address design goal 6
  - Simple network management protocol (SNMP) and NetFlow address design goal 7

Challenges faced by the Internet

- Security: The lack of security is worrisome
  - The availability of address to the upper layers (a violation of layering)
- Mobility: Application developers find little support for new mobile applications and services
  - Both logic and physical connections have to be torn down
- Reliability and availability: has to meet increasing user expectations of the Internet crucial role in both business and private life
- Diagnostics: Tools for root cause analysis is limited

Challenges faced by the Internet

- Scalability: The routing system, the address space is running out (IPV4)
- Quality of services: rely on middle boxes and overlays; it is not clear how and where to integrate different levels of QoS into the architecture
- Economics: How the network and services providers continue to make a profit
  - Bit transfer becomes a commodity service with very low marginal profit

Architecture design

- Incremental: with incremental patches
  - Practical, since we have a large infrastructure in use
  - Make the systems much more complex and difficult to manage; and well-provisioning enables this and covers the potential problems
- Clean-slate: redesign from the scratch
  - Offer improved and “clean” abstractions and/or improved performance; e.g., all the middle boxes and patches become built-in
  - The current Internet can provide insights on how
  - Not practical
  - E.g., Information-centric networking

References

- D. Clark, The design philosophy of the DARPA Internet protocols, *Proceedings of ACM Sigcomm*, 1988.
- A. Feldmann, Internet clean-slate design: What and why?, *ACM Sigcomm Computer and Communication Review*, 2007.