

PA197 Secure Network Design

3. Security Architectures I

Eva Hladká, Luděk Matyska

Faculty of Informatics

March 2, 2022

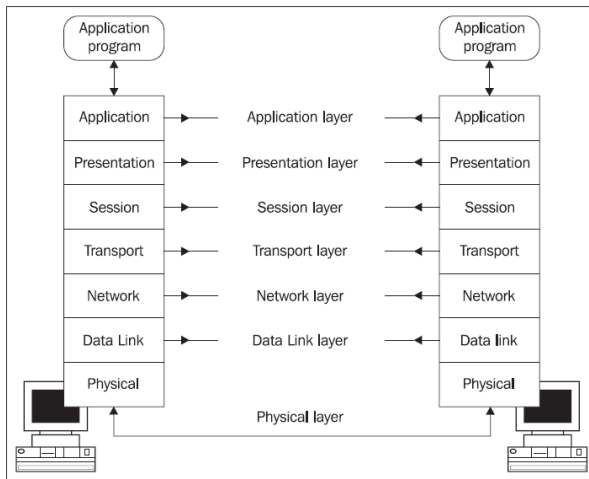
Content

- 1 Basic principles and protocols
 - Common Internet protocols and their resilience
 - Redundancy principle in network design
- 2 Secure and resilient routing
 - Link and Path Protection
 - Link Aggregation
 - Multipath routing
- 3 Resilient overlay networks
- 4 Secure DNS

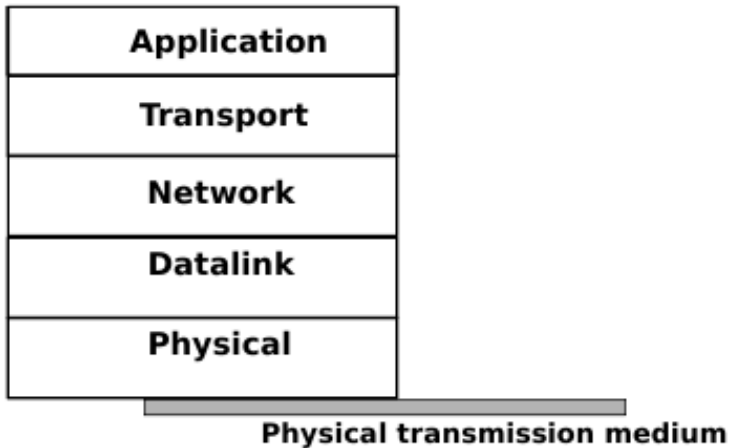
Internet protocols

- Networks rely on protocols
 - a **communication protocol** is a set of rules that define how data are exchanged between computers
 - A protocol defines
 - syntax
 - semantics
 - synchronization
- independent on the implementation
- Protocol layering
 - basic design principle
 - allows decomposition

OSI Reference Model



TCP Reference Model



Transport Layer

- Communication between application programs
 - end-to-end
 - whole messages
 - split into packets at Internet layer
- **Transmission Control Protocol (TCP)**
 - reliable transport
 - flow/congestion control
- **User Datagram Protocol (UDP)**
 - unreliable transport
 - connection-less

TCP—reliable protocol?

- Provides reliable transport
 - byte-oriented stream
 - guarantees ordering
 - guarantees integrity
- However, the guarantees not prone against active adversary
 - man-in-the-middle: easy to modify
 - source address
 - content
 - sequence prediction attack
 - injects counterfeit attacks

Redundancy principle

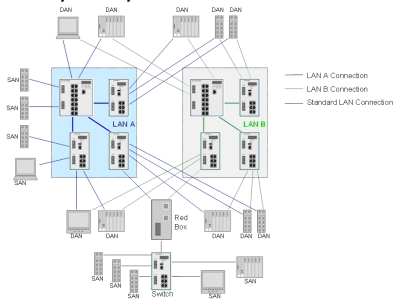
- Redundancy: an old engineering principle
 - do not create (remove) any **single point of failure (SPOF)**
 - failure in one component should not crash the system
- A design principle to **prevent a failure** of the whole system
- It comes with added cost and complexity
- Cost implications
 - more components than actually needed to perform an operation
 - cost limits the **extent** of redundancy
 - i.e. how many components could fail before the system goes down
- Complexity implications
 - adding components makes the system more complex
 - higher complexity increases the probability of a failure
 - RYF-principle (Robust Yet Fragile)
- Redundancy **is not** a backup

Redundancy in network design

- Needs to have multiple instance of everything that can possibly fail
 - links
 - ports
 - active elements

Everything must be at least doubled (no SPOF)

- *The principle demonstration*



Availability

- Redundancy is a tool, availability is the goal
 - we would like to have **always available** systems
 - in practice, **high availability** is achievable
- Redundancy contributes to availability keeping the system up in presence of failures
- Reaction in case of failure:
 - **failure detection**
 - **failing over**
 - **reconnection**
- Network protocols have different parts implemented
 - routing used as the next example

Link protection

- A scheme to mitigate from network failure
 - link layer
 - end nodes of the link responsible for failover
- Basic principles
 - failure recognition
 - selection of redundant path
- **Bi-directional Line Switched Ring (BLRS)**
 - every link can carry payload and backup traffic at the same time
 - four fiber
 - two fibers for working
 - two fibers for protection/backup
 - two-fiber
 - work and backup shared
 - half the capacity for backup

Link protection–Ethernet

- Link aggregation
 - multiple links carry the traffics
 - failure of a single link reduces the overall throughput
 - the redundancy principle in practice
- Initially static configuration
 - high probability of configuration error
 - not able to properly **detect the failure**
- Dynamic configuration
 - Link Aggregation Control Protocol (see next slides)

Path protection

- Protect from network failure in connection oriented networks
- Ring
- Optical Mesh
- MPLS (Multi Protocol Label Switching)
 - **packet protection scheme**
 - two link/node disjoint paths between ingress and outgress routers
 - outgress router compares packets
 - uses double the bandwidth
 - **global path protection**
 - primary and backup label switched path (LSP) are computed and setup
 - the backup may not fulfill the SLA
 - backup LSP does not carry traffic
 - **fault indication signal** inform ingress router to switch to backup LSP

Link aggregation

- Combining (aggregating) multiple network connections to
 - increase **throughput**
 - provide **redundancy**
- The lowest three layers
 - layer 1: IEEE 1901 (power line) or IEEE 802.11 (wireless)
 - layer 2: across switch ports
 - layer 3: round robin scheduling
- Provides **load balancing** and **failover** over the links
- **Link Aggregation Control Protocol (LACP)**
 - IEEE 802.3ad standard to negotiate bundled links between switches
- Packet reordering problem

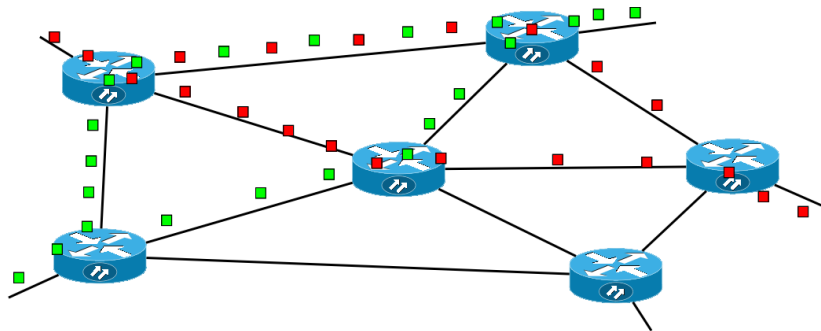
Link Aggregation—Proprietary Protocols

- Vendor's protocols
 - CISCO: EtherChannel and Port Aggregation Protocol
 - Juniper: Aggregated Ethernet
 - Nortel, AVAYA: Multi-Link Trunking family of protocols
 - Huawei: Eth-Trunk
- Linux Bonding driver
 - bonds several NICs into a logical channel
 - can work in **active** or **passive** mode
 - fault tolerance (both) and load balancing (passive)

Multipath Routing

- Benefits
 - fault tolerance
 - increased bandwidth
 - improved security
- Types of paths
 - overlapped
 - edge-disjoint
 - node-disjoint
- Problems with per-packet multipath routing
 - variable path MTU
 - variable latencies
 - packet reordering
 - debugging
- Equal-cost multipath routing (ECMO)
 - IEEE 8021Qbp (2014)

Multipath Routing—Picture



OLSR

- **Optimized Link State Routing Protocol**
 - RFC 3626
- IP routing for mobile ad hoc networks
- Basic principles
 - limited flooding: 2-hop neighbor
 - **multipoint relays** (MPR)
 - only MPR can source **topology control** packets
 - limits the extent of knowledge shared among nodes
 - not all links are advertised
 - no reliable algorithm
 - a pro-active algorithms: route computed before used

Reliable routing in MANET

- MANET a challenging environment for reliable routing
 - node mobility
 - limited battery capacity
 - low reliability of data transfer medium

Reliable routing necessary for mobile ad hoc networks

- Basic principles:
 - proactive routing
 - reactive routing

Proactive routing in MANET

- Similar to routing in Internet
- Example: Destination Sequence Distance Vector (DSDV)
 - periodic exchange of routing information
 - independent of actual payload transport
- Drawbacks:
 - large number of control messages
 - high load on the network nodes
 - frequency must relate to the “mobility” of nodes within the network
 - can be very high or the routing info is obsolete
- Not really suitable for MANET

Reactive routing in MANET

- Reacts on data transfer needs
- **Route discovery** and **Route maintenance**
 - responsibility to find a route lies with the source node—discovery
 - every node detects topology changes
- Examples:
 - **Dynamic Source Routing (DSR)**
 - **Ad-hoc On Demand Distance Vector Routing (AODV)**
- **Flooding** mechanisms to discover the route(s)
- Naive approach: select the shortest path
 - suboptimal in MANET
 - creates congestion in the center of the network
 - “shortest” may not survive node mobility
- **Multipath routing** proposed as a better alternative

Multipath Routing in MANETs

- Several variants
 - delay aware protocols
 - reliable multipath protocols
 - minimum overhead
 - energy efficient
 - hybrid approaches
- Follow: Mohammed Tariquea, Kemal E. Tepeb, Sasan Adibic, Shervin Erfanib: *Survey of multipath routing protocols for mobile ad hoc networks*. J. Network and Computer Applications, Vol. 32(6), pp 1125–1143, 2009
 - <http://www.sciencedirect.com/science/article/pii/S1084804509001027>

Resilient overlay networks

- Introduced by Andersen:2001
- An architecture to support e2e communication to
 - detect network outages and performance degradation
 - recover from theseand do it fast (in terms of seconds even when used over the Internet)
- An application layer overlay over the “standard” network
 - monitor the liveness and quality of Internet paths
 - take decision where to actually route each packet
- Optimizes application-specific routing metrics

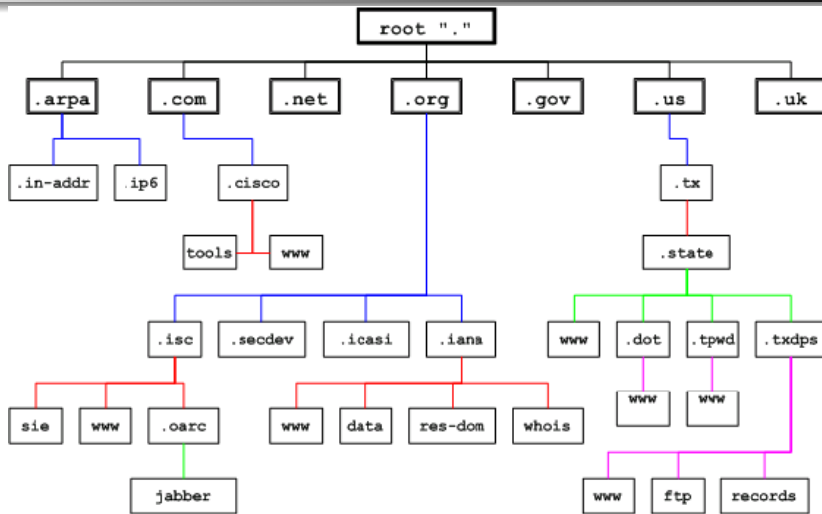
RON

- Some problems with “standard” routing
 - routing metrics are not modifiable by users
 - interdomain routing usually not too sophisticated
 - quality measurements usually only intra-domain
- RON concept
 - move routing to the end systems
 - but not to the applications
 - it is still a network
 - small scale (tens of RON nodes only)
 - independent end to end monitoring used for routing decisions
- Sophisticated applications (e.g. videoconferencing), but also coordinated reaction to DOS attack
 - cooperative defense
 - RON nodes used for
 - detection near malicious data target
 - traffic control near source
 - coordinated response through RON nodes

Domain Name Service (DNS)

- Associates host names with IP addresses
- Bidirectional
 - forward record: from host to IP address
 - reverse record: from IP address to host name
- Hierarchical distributed architecture
 - root servers
 - authoritative servers
 - data caching
- Specific vulnerabilities
 - Denial of service
 - information disclosure (reconnaissance before attack)
 - (authoritative) spoofing
 - cache poisoning

DNS Structure



DNSec

- DNS security extension
 - uses PKI and digital signatures
- Server side
 - authentication
 - signed zone information
 - storage for public keys
 - signed query answers (A, MX, PTR)
- Client (resolver) side
 - origin authentication (authoritative)
 - data integrity
 - authoritative denial of existence

Summary

- Networks serving critical systems—the reliability of network as a whole becoming increasingly important
 - in some networks (e.g. MANET), the reliability is a necessary condition for proper operation
 - Redundancy used as a standard engineering technique to achieve robustness
 - redundant systems more expensive
 - redundant systems more complex
- No “silver bullet” to solve the reliability requirement
- Presented examples of (more) reliable protocols
 - routing
 - resilient overlay networks
 - Secure DNS as another example of the application of the basic principles
 - Next lecture: Secure/Reliable data transport over the network