ECE 671 – Lecture 15

Application Layer Systems
Content inspection

Application layer systems

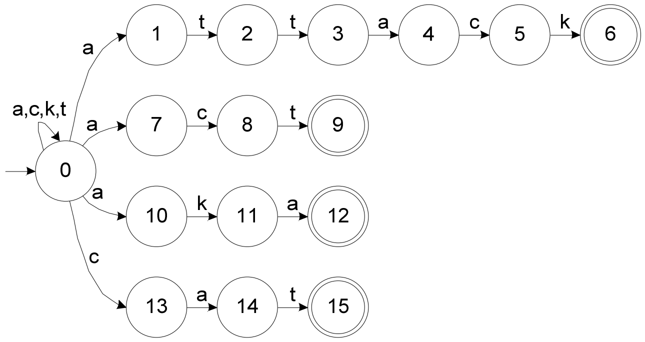
- Payload inspection in network systems
  - Monitoring
  - Security
  - Content blocking
  - Quality of service
- Our examples:
  - String matching for content filtering firewall
  - Load balancing for web server

Pattern matching

- Given:
  - Alphabet: {a,c,k,t}
  - Pattern: attack
- Goal:
  - Match packet payloads against pattern
- Problem variants:
  - Exact string matching
  - Regular expression matching

Exact string matching

- Nondeterministic finite automaton (NFA)
  - Automaton can be in multiple states at the same time



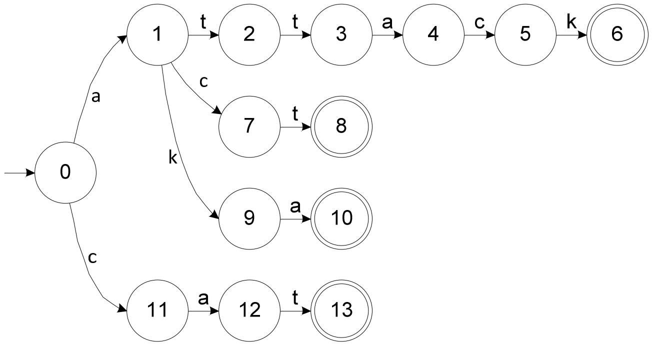
Exact string matching

- States for acaattack:

Input	Set of states	Match?
-	{0}	no
a	{0,1,7,10}	no
c	{0,8,13}	no
a	{0,1,7,10,14}	no
a	{0,1,7,10}	no
t	{0,2}	no
t	{0,3}	no
a	{0,1,4,7,10}	no
c	{0,5,8,13}	no
k	{0,6}	yes (“attack”)

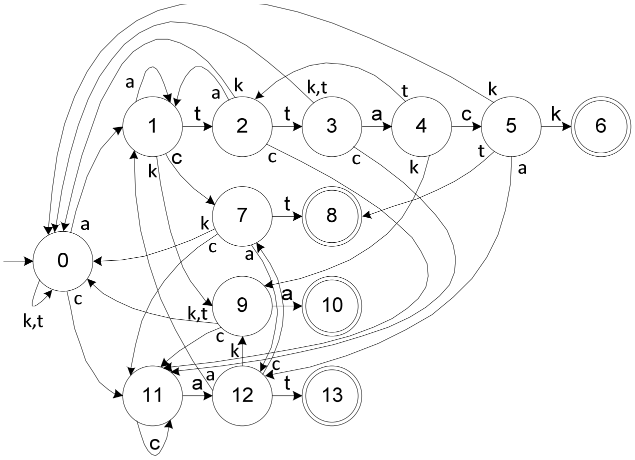
Exact string matching

- States for deterministic finite automaton (DFA):
  - What are default transitions?



Exact string matching

- DFA with default transitions:

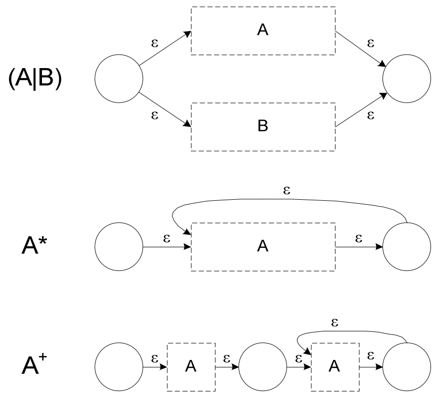


Regular expression matching

- Richer expressions
  - Alternatives: A|B
  - Zero or more occurrences: A*
  - One or more occurrences: A+
- Example:
  - AB+: AB, ABB, ABBB, ABBBB, …
  - A(B|C)*: A, AB, AC, ABB, ABC, ACB, ACC, ABBB, …

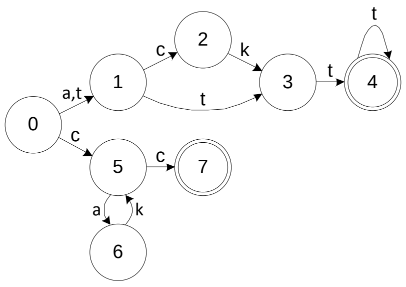
Regular expression construction

- NFA with epsilon transitions:



Regular expression construction

- NFA to DFA conversion
  - Closure of all states (to remove epsilon transitions)
  - Subset construction (parallel NFA states in single DFA state)
- Example: ([a,t](ck|t)t+|c(ak)*c)

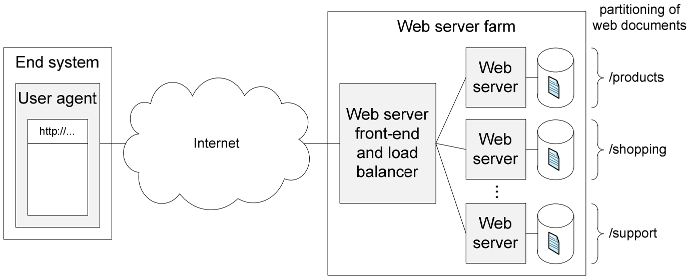


Content inspection in Internet

- Intrusion detection system (IDS)
  - Check for malicious content in packets
  - Example: known attacks, exploits, malware, etc.
- How to get "signatures" of malicious content?
  - Few tools
  - Mostly created by hand
- Open source tool: snort
  - www.snort.org

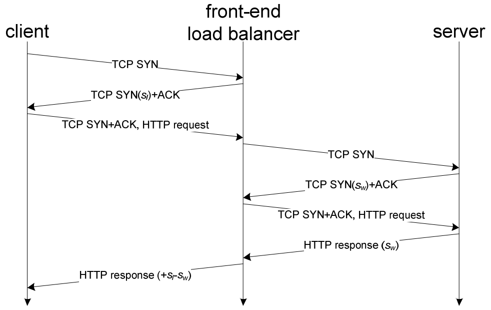
Load balancing web server

- Large servers may not keep all pages on one system
  - Need to distribute requests between servers
  - What is the challenge?



Load balancing web server

- Problem is TPC connection setup
  - URL in request only known after connection is established
  - Initial connection setup cannot be routed to actual server
  - Load balancer intercepts and “glues” connections



Network systems

- We have seen all major network systems
  - Interface cards
  - Bridges/switches
  - Routers
  - Transport layer systems
  - Application layer systems
- Next
  - Queuing theory
  - Scheduling
  - Network security