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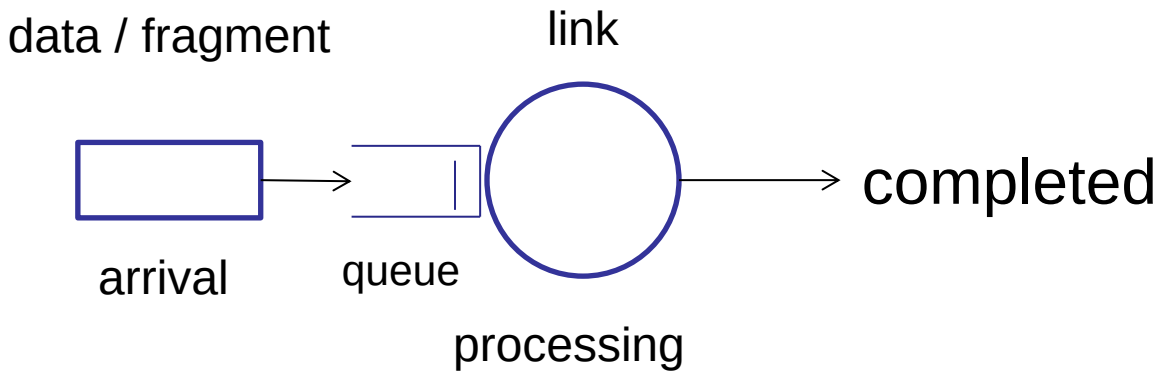
Network Analysis

2b) Deterministic Modelling beyond Formal Logic

A simple network model

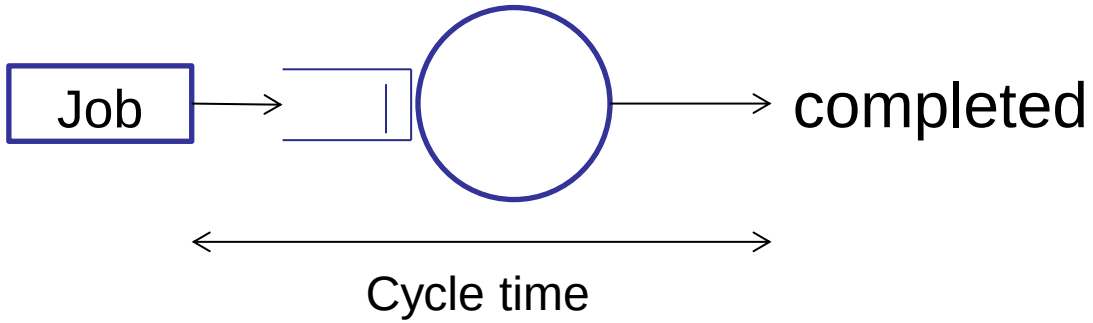


- When deterministic?
  - Both arrival process and processing process deterministic.
  - E.g. 1 arrival per 10 ms, processing takes 3 ms.

- Deterministic != simple
  - E.g. „3 arrivals at the same time every 100 ms“ is also deterministic.
  - Can be more complex, processing can depend on size.

- Essential for being deterministic: events are known in advance (can be calculated)

Terminology

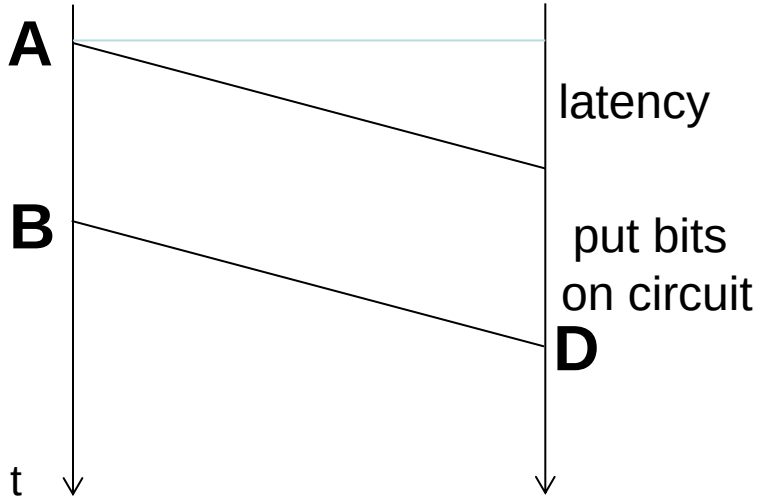


- CycleTime
  - Time from arrival till completion.
- Job
  - Jobs arrive and will be processed by the system.
  - We may often call them packets or other names in the context of networking.
- Queue
  - Can be of limited or infinite size
  - Has a queuing discipline: a way to order jobs (e.g. FIFO first in first out)

How realistic is that?

- Circuit Switching
  - Link / network shared, yet the bits on the line belong to certain circuits so that they can be forwared immediately (e.g. classic telephony)
  - Deterministic processing time
  - Arrival deterministic unless user-side load is considered.

- Analysis like in chapter 1 (circuit switching, medium access in switches full-duplex networks, …)
  - The network card puts a packet of a given size on the line. Serialization delay and propagation delay determine exactly the time T from A to D for a fixed packet size.
  - Note, no matter when, the packet will always succeed to reach D after time T.



Deterministic Modelling

- Now, is this anywhere near reality?

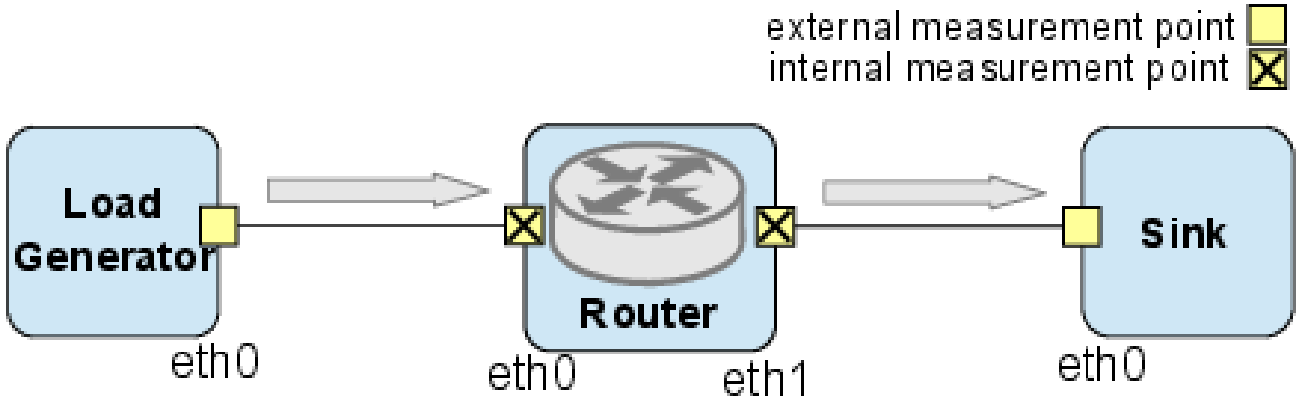
→Lets look at software router performance.

- Now, is this anywhere near reality?

Software Router – Throughput Measurement Setup

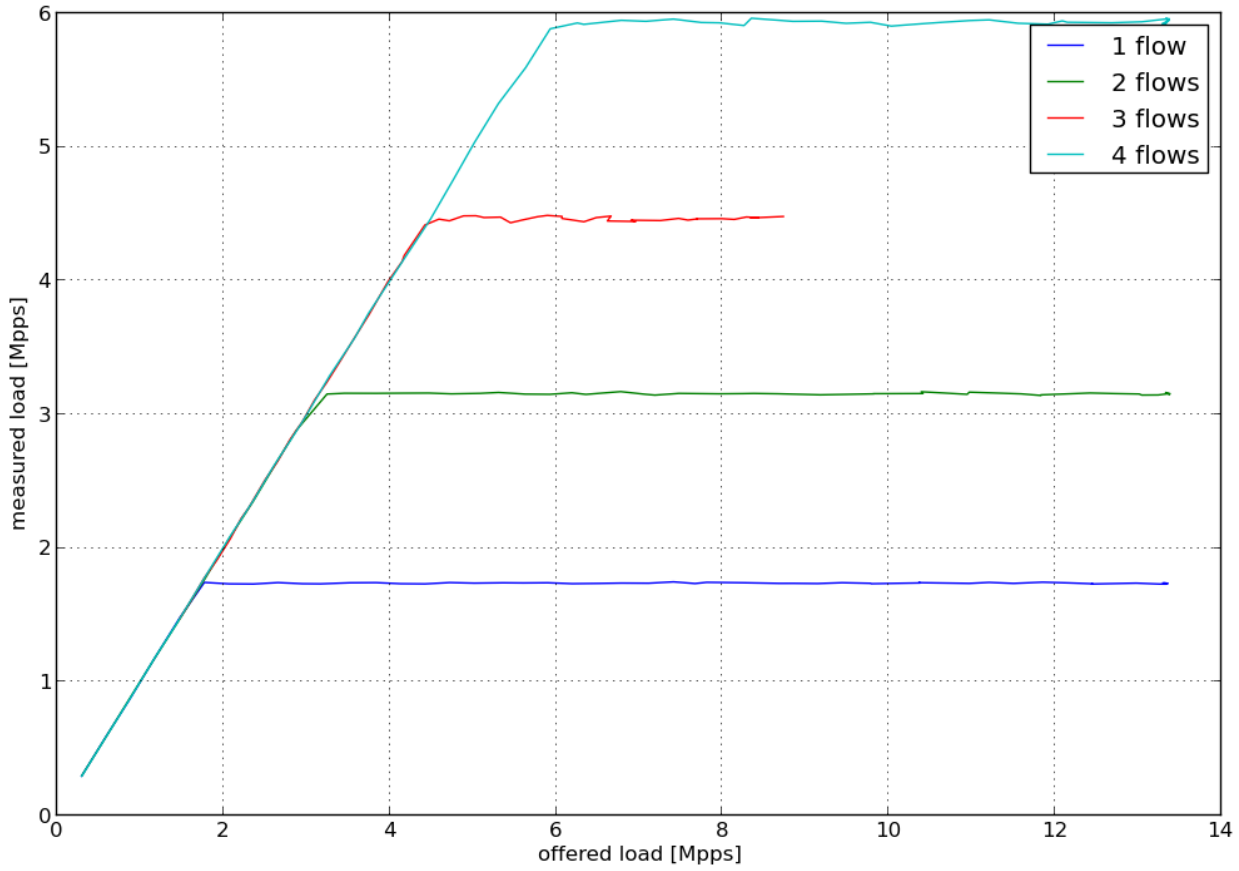
- **Goal:** Measure the maximum throughput of a Software-Router

- Load Generator produces traffic with a constant bitrate
  - Packet size 64 – 1518 Bytes
  - Packet rate up to 14,88 million packets/s (= 10Gbit/s @ 64B packets)
  - 1 – 4 concurrent flows (= 1 – 4 cores for packet processing)



SW-Router Input / Output Rates (64B Packets)

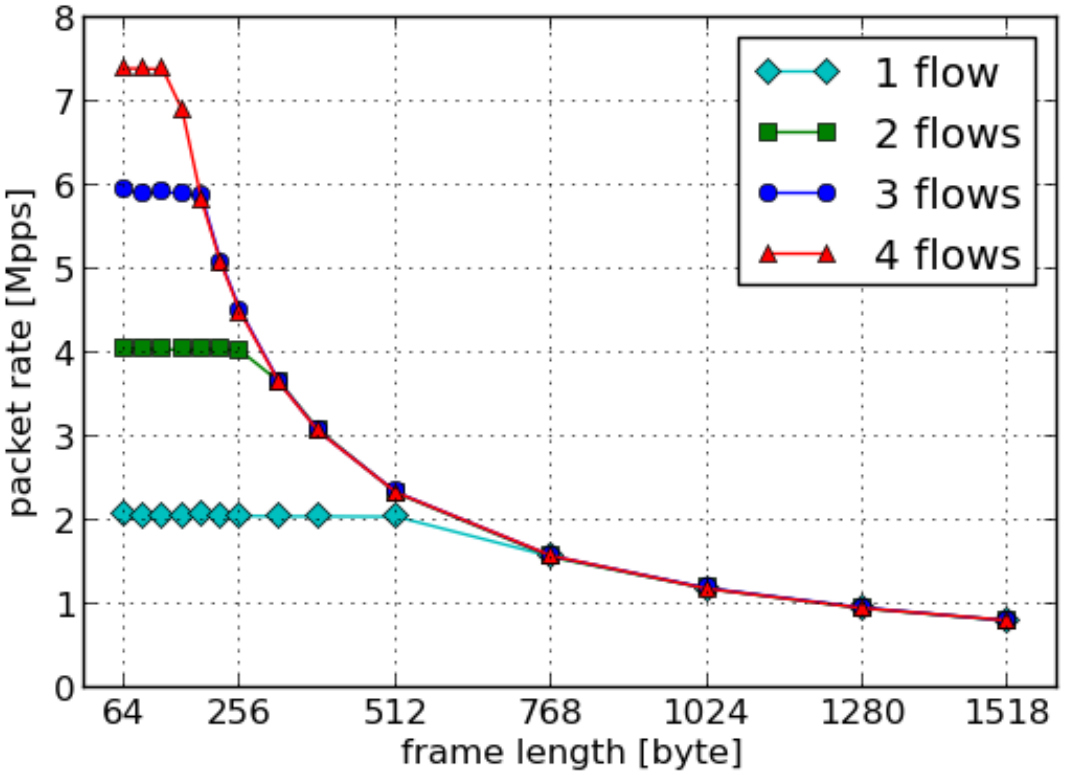
- Linear growth (input = output) of the output rate until the CPU is fully utilized
- Constant output rate at full CPU utilization (even more input does not affect the output rate)
- Roughly linear growth of maximum output with number of utilized cores



Mpps = Million packets per second

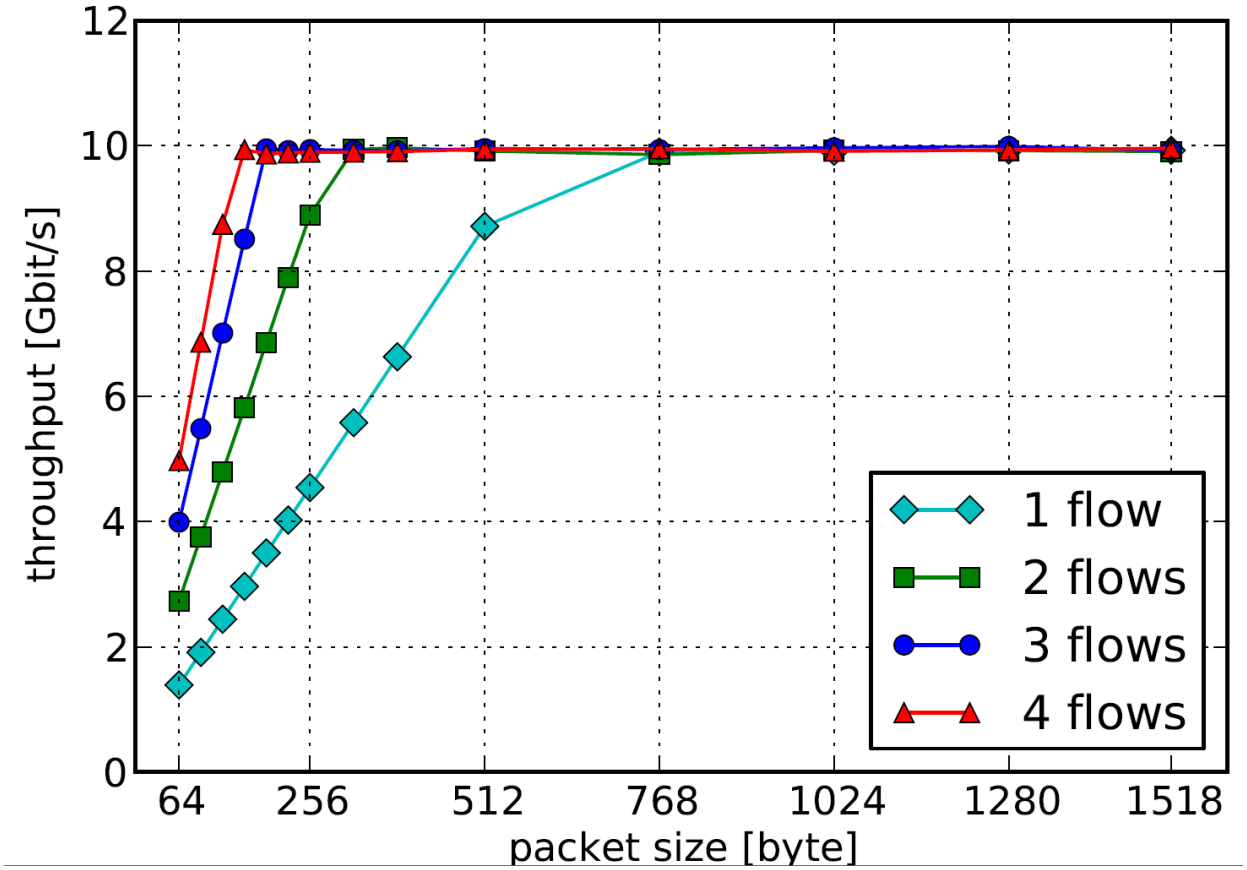
SW-Router – Maximum Packet Rates vs. Packet Size

- Each data point is an own measurement (as on the last slide)
- For small packet sizes the CPU is the bottleneck
  - Constant packet rate → Packet rate independent from packet size
- For large packet sizes the link speed (10 Gigabit/s) becomes the bottleneck
- Again, linear growth of packet rate with number of utilized cores



SW-Router – Maximum Throughput vs. Packet Size

- Similar to the last slide, but with throughput (Gbit/s) instead of packet rate
- Linear growth with the packet size until hitting the link bottleneck at 10 Gbit/s



SW-Router – Conclusions

- For the aggregate of the measurements
  - Linear relationships have been found.
  - Throughput directly related to situation-specific bottleneck.
  - Seemingly deterministic behaviour.
- For individual packets the situation may be different.

Other forms of deterministic models

- It is common that algorithms and analysis ignore stochastic aspects.
- Situation, however:
  - System is most likely not determinstic.
  - Changes can occur.
- Chances for deterministic modelling
  - Changing or random aspects are small and can be neglected for some kinds of analysis or in algorithms.
  - System is assumed static for a certain amount of time.
    - Change usually slower than actual problem.
    - Random aspects less relevant for average case behaviour
    - Significant change will trigger new analysis.

Other forms of deterministic Modelling

- Example: Routing / Link-state Routing
  - Routers broadcast information about their links.
  - All routers use this information to calculate a graph.
  - The graph is seen as model for the network and algorithms operate in the graph.
  - This graph is seen as fixed for some (unknown) time.
  - Routing tables are calculated in the graph according to optimization goals.
    - Usually based on a shortest path tree.

- So, forwarding tables in the routers assume that the entries are valid for a some period of time so that paths do not have to be searched for for every arriving packet.