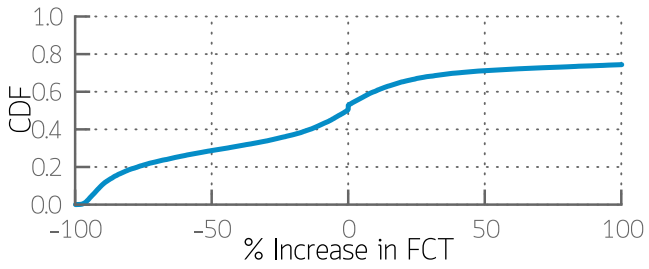
Turbo

- Need ultra-low latency remote procedure calls.
  - 5-10 us in short term; 1-2 us in long term (RAMCloud)
  - 2us x 10Gbps = 2.5KB = Bw-delay product
  - RDMA

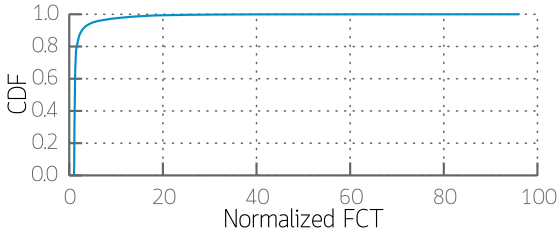
- **Initial Approach**: We started by taking trying to remove buffering from the network.
  - Advantages:
    - Predictable delays per packet
    - Finer grained retransmissions (reduces latency if loss is kept low (?))
    - Cost
    - Simplicity of design – Priority scheduling and dropping are O(1).

- Question: What network protocol to use?
- Looked at how existing approaches perform
  - TCP:
    - Works quite well for some flows
    - But really poorly for others
    - Very low utilization – Could only sustain load-factor of 0.4
    - Tried modifications to TCP with packet jittering with similar results



  - State of the art: pFabric:
    - Analyzed its performance when buffers are very small
    - It performs poorly (graph to be redrawn)

- Looking from a different perspective:
  - pFabric claims near-optimal performance (though with non-trivial buffering, 10x the bw delay product we aspire to achieve).
  - Issues
    - Can cause starvation – a plot of normalized CDF of pFabric shows that flows can be 100x from the ideal and many of these are long flows but a better experiment to be done; Kaifei helping with this)



        - Dead packets can cause suboptimal utilization
        - Quite far from optimal using a sane metric – comparing averages of two systems
        - (Secondary) Complicated design state for every flow (to select the earliest packet from the highest priority flow)
    - Overhead that pFabric induces
        - pFabric adds around 18% byte overhead in terms of the packets that get delivered to the NIC
        - But many of these packets get dropped at the NIC and the network overhead is 5%.

- **Current approach**
    - Formalize the global optimization problem (High Priority)
    - But we want a distributed solution
    - Break up the global optimization problem into locally executable chunks
        - E.g., utilization maximization by making sure that a packet that has already traversed (n-1) hops also gets scheduled on the last hop to prevent bandwidth wastage.
    - Compose the local (or separate) chunks to approximate the global solution
    - Our current mindset is to heavily leverage priorities – using ideas from OS techniques to assign scheduling priorities based on a number of ideas (e.g., Lottery scheduling idea implemented by making retransmissions at a higher priority). [More thought required]
    - This gives us an k-tuple of priorities; the theoretical question would be how to compose these priorities to get a single number to get close the global optimal.