Principles for Measurability in Protocol Design

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Network Measurement

- Fundamental to network operations, research, protocol design, and informing Internet policy development.
- Minimal support from stack today (`ping` is what you get)
  - Unintended features (e.g. `traceroute`)
  - Brittle hacks (e.g. passive TCP loss/RTT)
  - Inference (cf. any academic measurement paper)

Result:
Important questions are hard

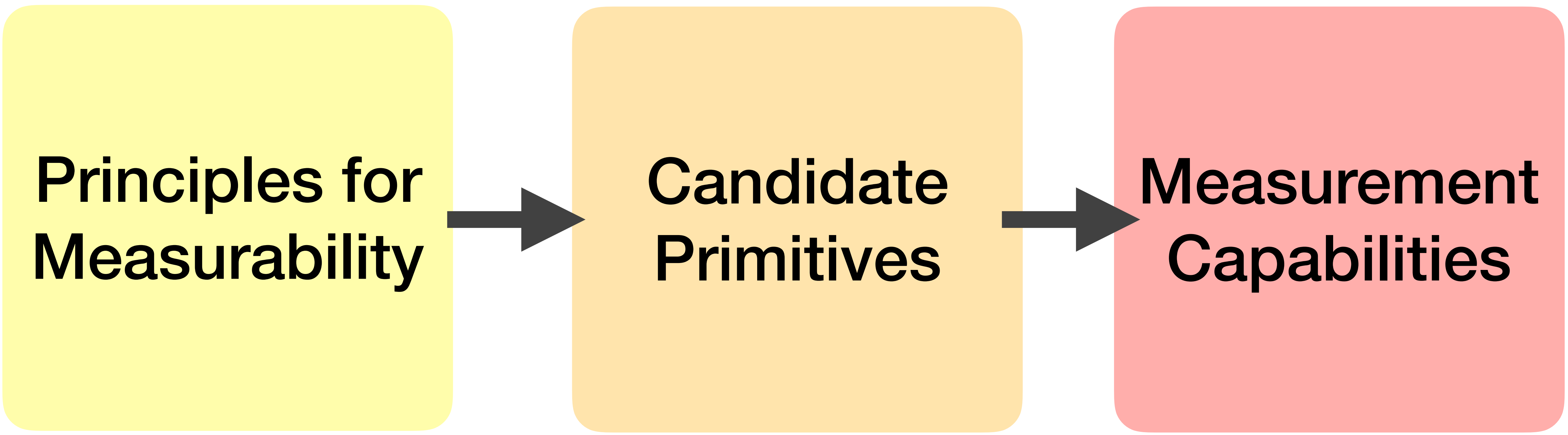
- What’s the best path to route traffic?
- What is the capacity or utilization of a link?
- How do networks interconnect?
- What AS operates a given router?

Even simple inferences are difficult!

- What's the delay between two hosts?
  - (Per-protocol traffic differentiation, path vs. host delay, asymmetry)
- What are the endpoints in a communication?
  - (NATs, CGNs, aliases, IPv6)
- How did packets arrive at a remote destination?
  - (order? modified? mangled? path? queued?)

What if we re-think the Internet protocol stack with measurability as a first-class component?

Approach



- Imagine packets carry measurement information: what should they include?
  - Goal: maximum benefit for minimum overhead

Principles for Measurability

1. Measurement should be **explicit**
   Reduces ambiguity, increases future-proof-ness
2. Measurement should be **in-band**
   Ensures measurement traffic treated similar to"real" traffic
3. The measurement **consumer** should **bear the cost**
   Shifts state and per-packet overhead offline, increases deployability
4. The measurement **provider** should **retain control**
   Ensures users know how measurable their traffic is
5. Measurement must be **visible**
   Increases transparency and trustworthiness in measurement
6. Measurement should be **cooperative**
   Follows from P3/P4, leverages existing middle/endpoint tussle

Candidate Primitives

(see the paper)

- End to End Information §4.1
  - Host Identification §4.1.1
  - Timing §4.1.2
  - Arrival §4.1.3

    focus of this talk
  - Integrity §4.1.4
- Hop-Specific Information §4.2
  - Topology
  - Queue Performance
- Accumulated Path Information §4.3
  - Path Change Detection
  - Path Queue Delay

    also covered briefly

Candidate Primitive: Timing Information §4.1.2

- TCP TSOPT (R ght...

  P2 In-Band
  P5 Visible

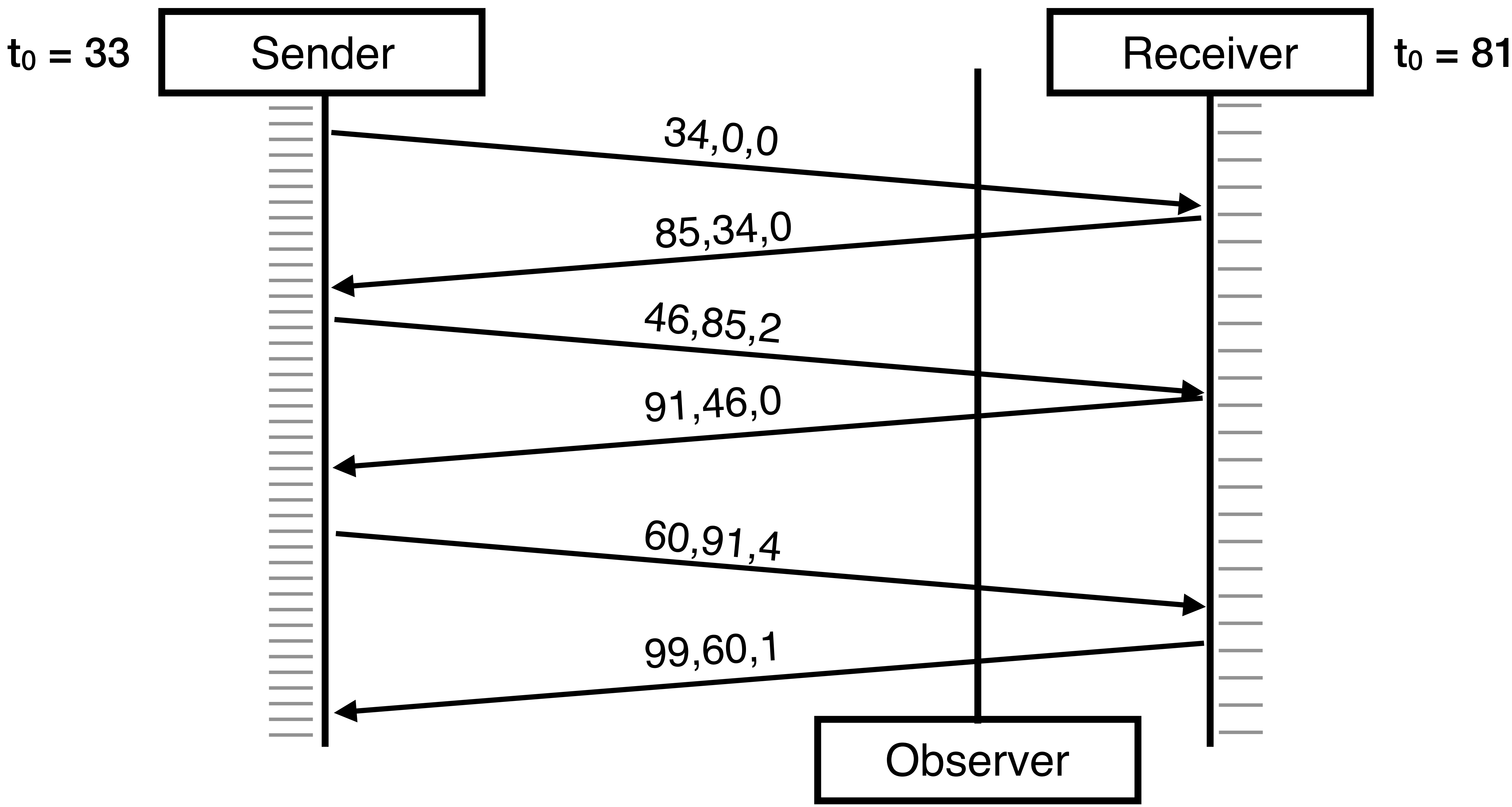
  - ...but not designed for passive measurement
- Approach: add a T_{now}, T_{echo}, T_{Δ} tuple to packets:
  - T_{now} = timestamp in constant-rate clock
  - T_{echo} en from peer

    P1 Explicit

  - T_{Δ} = ticks in constant-rate clock since T_{echo} seen
- Resolution-overhead tradeoff: can be sent on $^1/_n$ packets.

P4 Sender Control

Timing Information §4.1.2: RTT and Timing Measurement



Candidate Primitive: Arrival Information §4.1.3

- Makes pattern of loss and reordering visible in a transport-independent way.

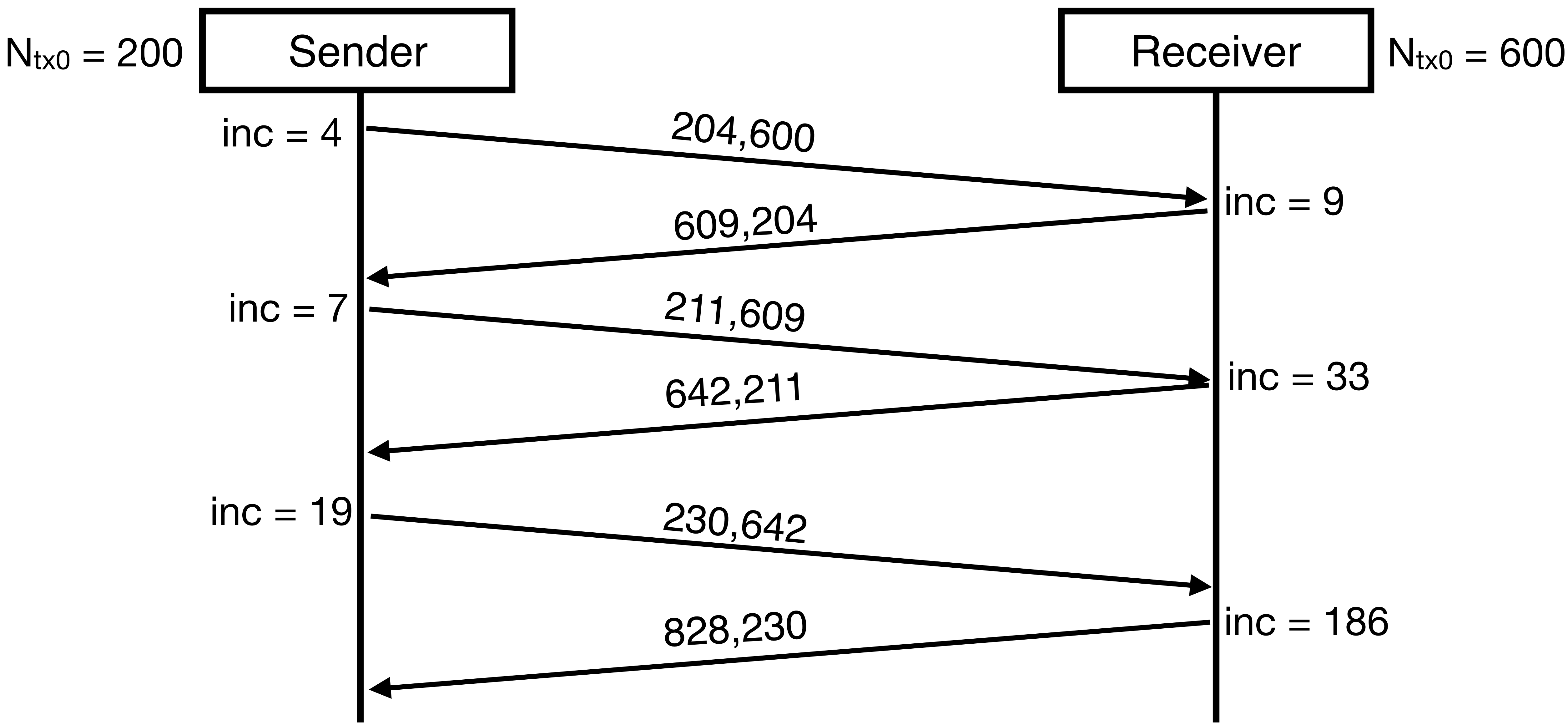
P1 Explicit
P5 Visible

- Each sender maintains a counter N_{tx} per flow:
  - Increment N_{tx} by a randomly-chosen but increasing number for each packet sent.
  - Maintain running sum of received N_{tx} values as $\sum N_{echo}$.
  - Send $\{N_{tx}, \sum N_{echo}\}$ on every packet.

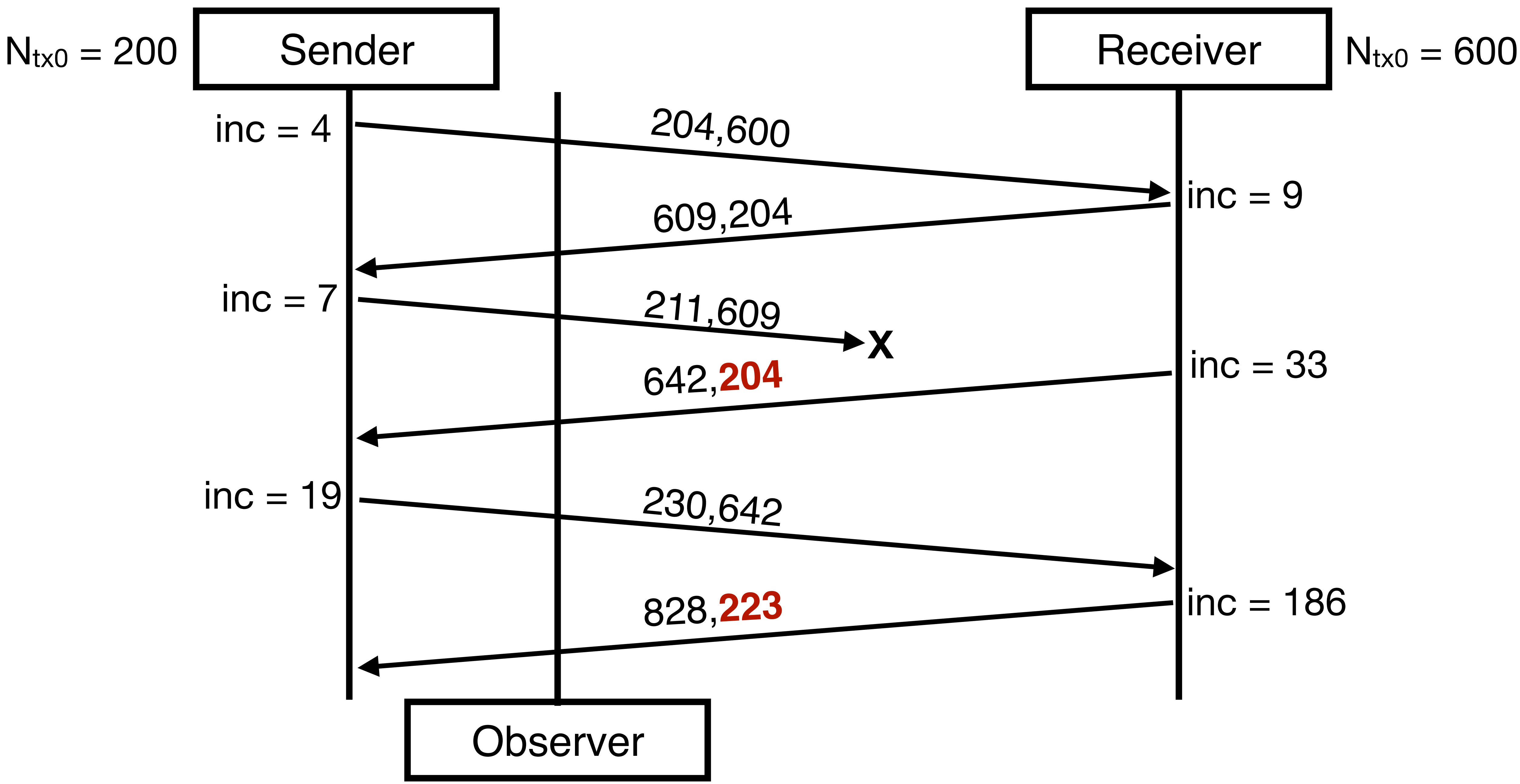
P3 Consumer Cost

- (inspired by Savage et al. *TCP Congestion Control with a Misbehaving Receiver*. ACM CCR 29(5), Oct. 1999.)

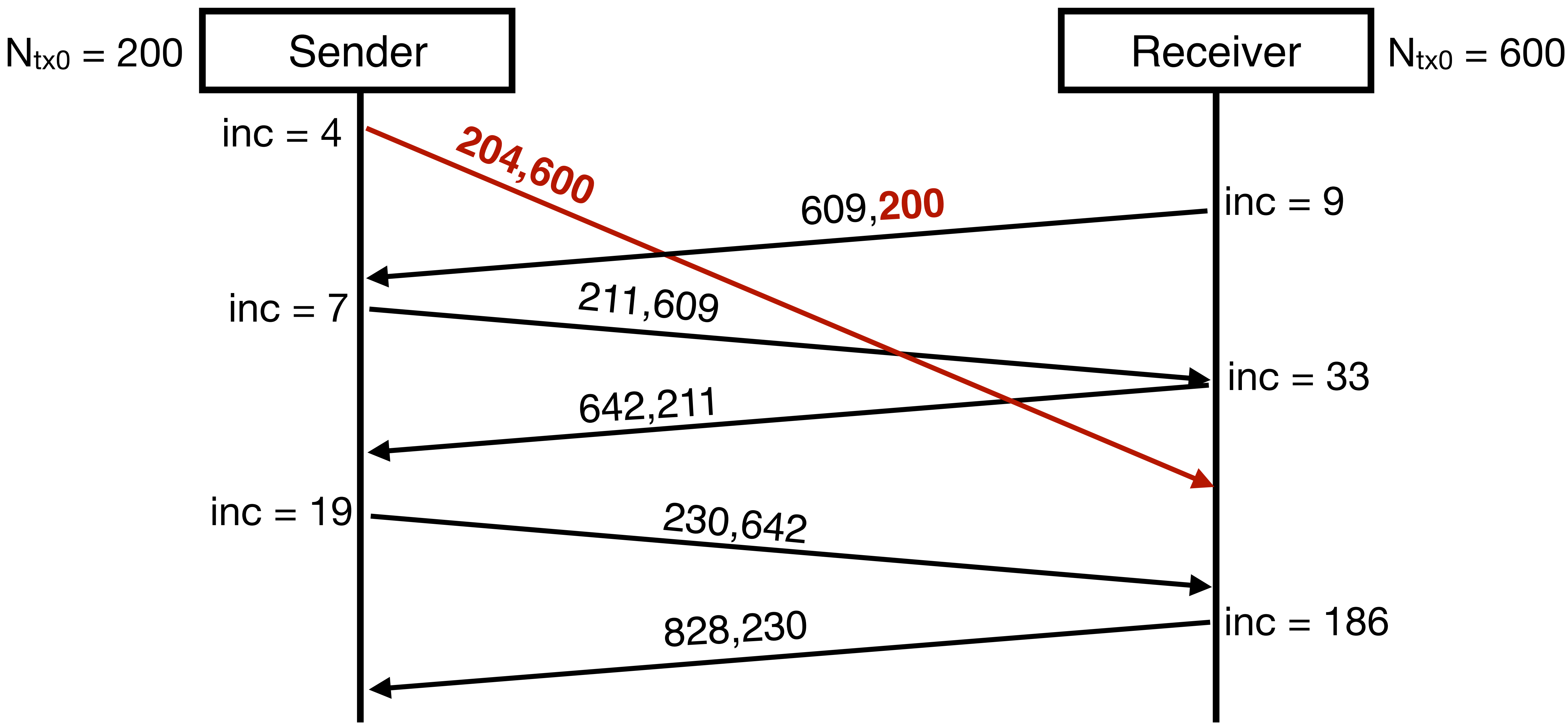
Arrival Information §4.1.3: General Case



Arrival Information §4.1.3: Loss Detection



Arrival Information §4.1.3: Reordering Detection



Candidate Primitive: Probabilistic and Triggered Stamping §4.2

P6 Cooperative

- Request for information to be added by router
  - at TTL *n* or with probability *p*
  - Performance diagnostics: $\{T_{now}, D_{queue}, C_{queue}\}$ tuple: replaces high-load queueing delay measurement.
  - Topology discovery: $\{AS, ID, IP_{in}, IP_{out}\}$ tuple: explicit replacement for tracreoute.

P1 Explicit
P5 Visible

- Useful in intradomain applications, with migration to interdomain usage.

Conclusions

- Network **measurement is critical.** We need better tools, and better tools **need better support from the network.**
- Propose guiding **principles** for viable measurement.
- Demonstrate candidate **primitives** that address long-standing, important real-world measurement problems.
- Position paper: spur discussion, debate, and **inform protocol development.**

- **Read the paper:** https://ccronline.sigcomm.org/wp-content/uploads/2017/05/acmdl17-60.pdf

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