The Observer Effect in Computer Networks

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Applied Networking Research Workshop (ANRW)
2024

The Uncertainty Principle in Physics

The position and momentum of a particle cannot both be measured precisely.

The uncertainty relation:

$$\Delta x \cdot \Delta p \geq \hbar$$

- Δx: Uncertainty in position
- Δp: Uncertainty in momentum
- $\hbar$: Plank's constant

Werner Heisenberg

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The **Observer Effect** in Physics

The measurement of a system affects the measured system.

$$\Delta x \cdot \Delta p \geq \hbar$$

The uncertainty in the position of a particle, measured using a Gamma ray.

The uncertainty in the momentum, which is affected by the Gamma ray.

Werner Heisenberg

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This Paper: **The Observer Effect in Networks**

The act of measuring the performance of a network affects the network's performance.

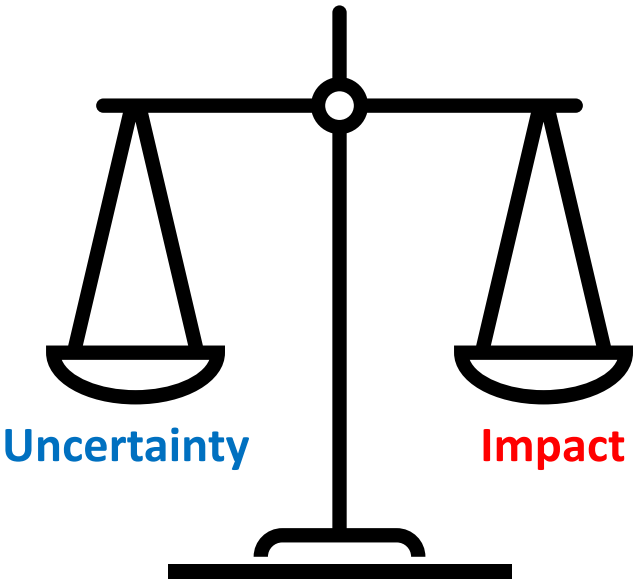
The uncertainty relation in networks:

$$\Delta \mathrm{M} \cdot \Delta \mathrm{P} \geq \eta$$

The **uncertainty** in a measured metric M

The **impact** of the measurement on a performance metric P

The **observer factor**



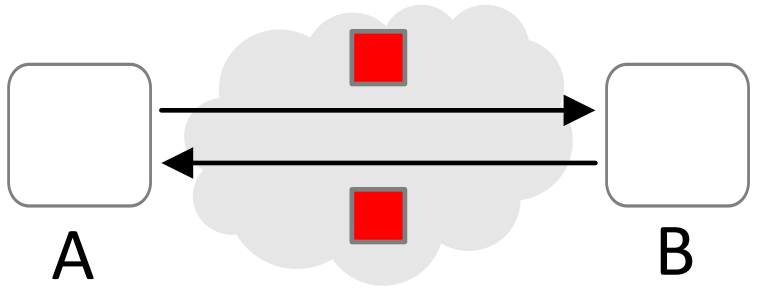
Understanding the Observer Effect in Networks

Measurement has **overhead**.

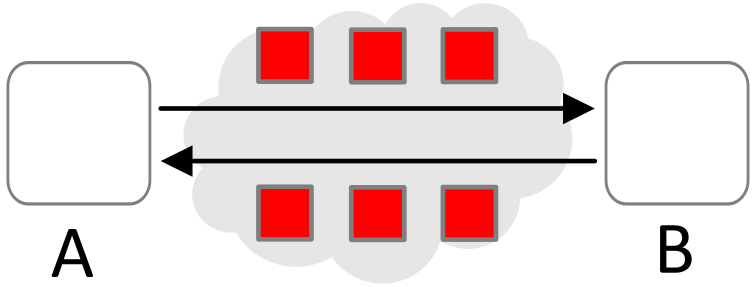
The overhead may affect the network performance.

Example:

Active measurement: performed by exchanging control messages.



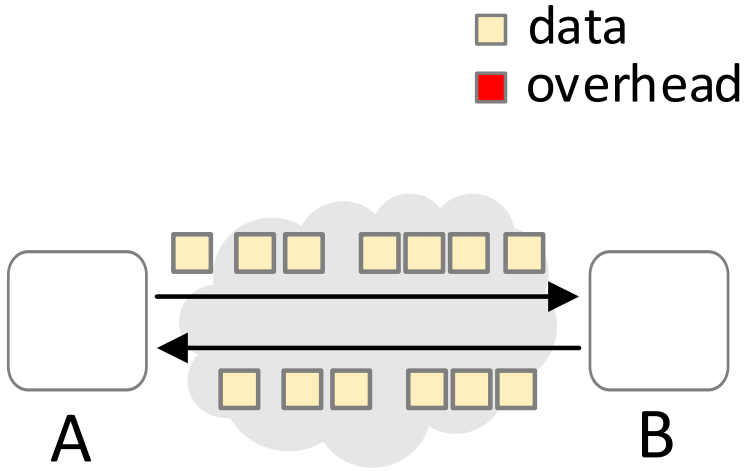
Less uncertainty ➔ more **overhead**.



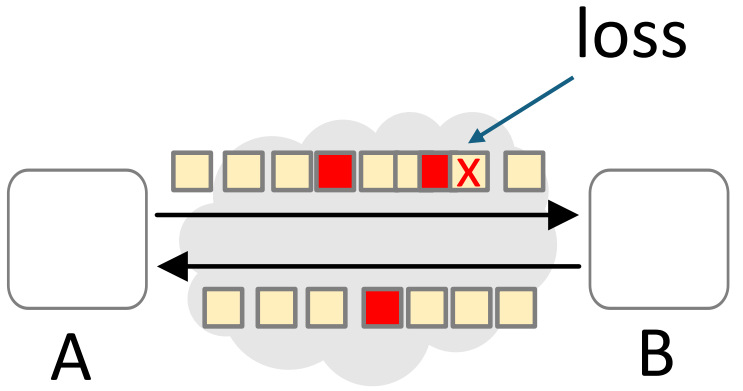
Why Overhead Matters

Example:

High load without measurement.



The measurement overhead increases the load and can cause packet loss.

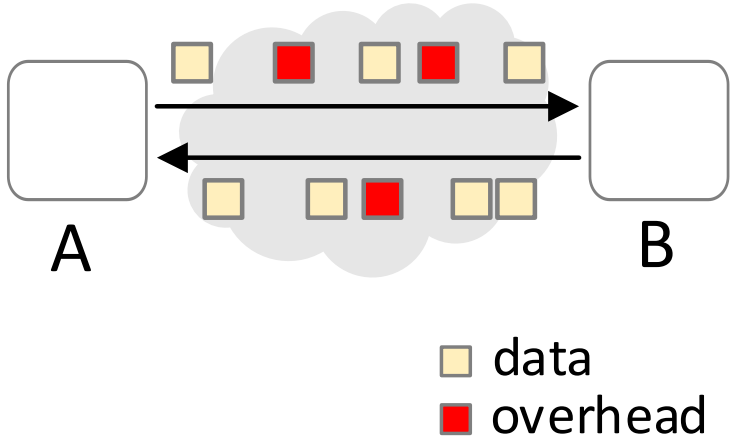


Why Overhead Matters

Overprovisioned network:

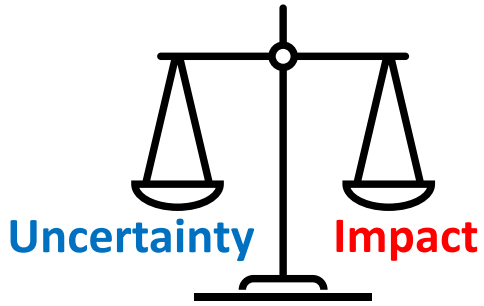
Network is not loaded
➔ Overhead does not cause packet loss.

Excess resources can accommodate the measurement overhead.



However, excess resources have a **cost**.

The Impact of the Measurement Overhead



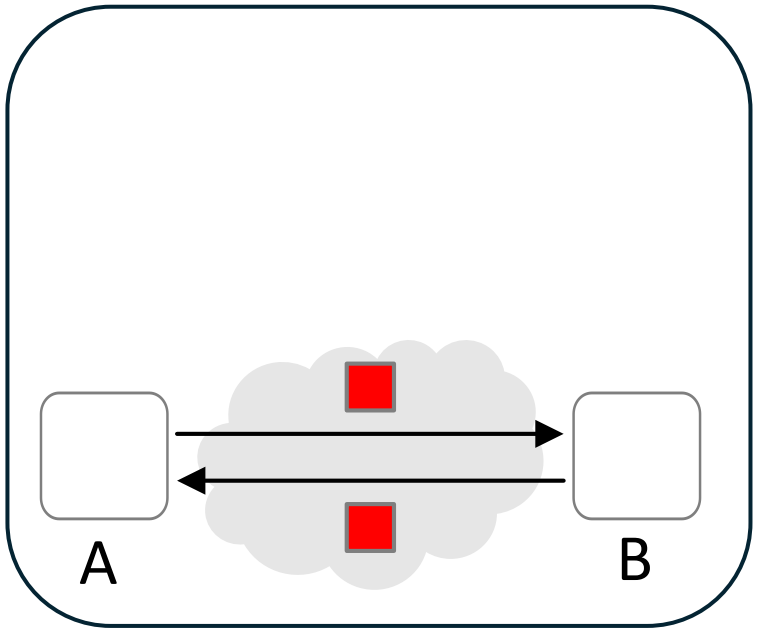
Various ways to quantify the impact

- Packet loss ☒
- Power
- Overprovisioning cost $
- Excess traffic charges

In this work we quantify the impact by the overhead **traffic rate** [bits per time unit].

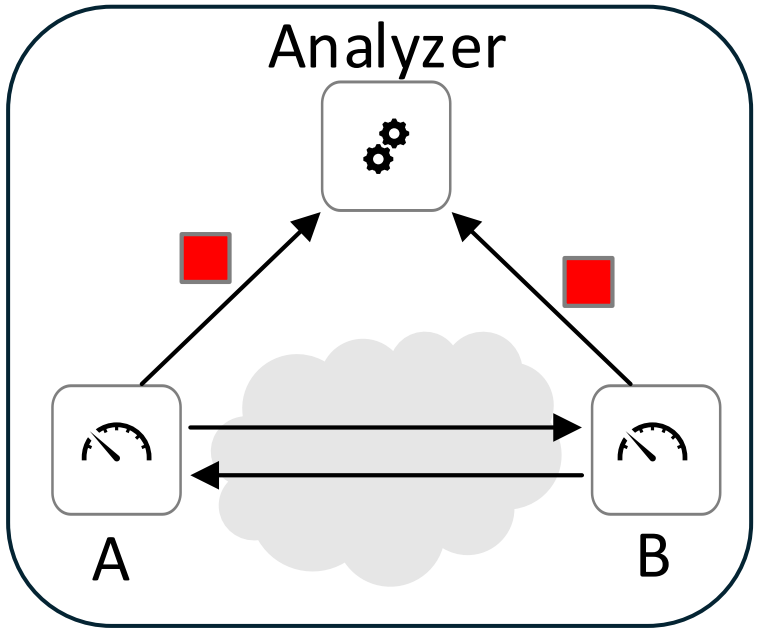
A Classification of Measurement Methods

Active measurement



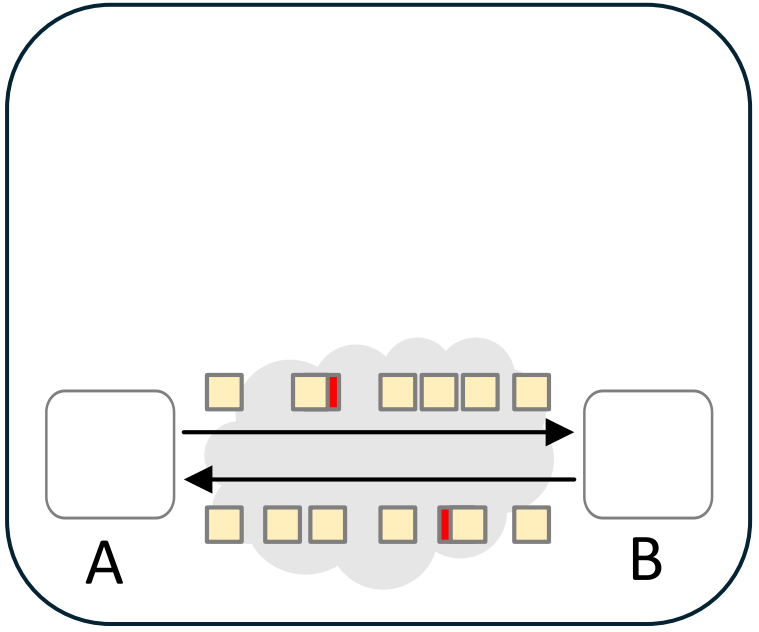
Impact: rate of control plane messages [bits per second per flow].

Passive measurement



Impact: rate of management plane messages sent to the external analyzer [bits per second per flow].

In-situ measurement

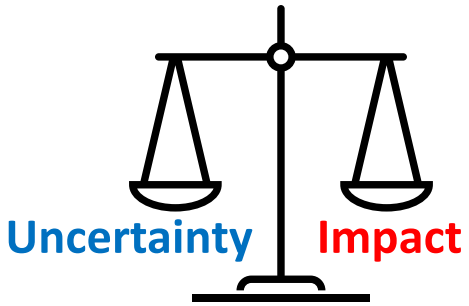


Impact: average rate of data plane overhead bits [bits per second per flow].

The Scope of our Theoretical Model

We focus on:

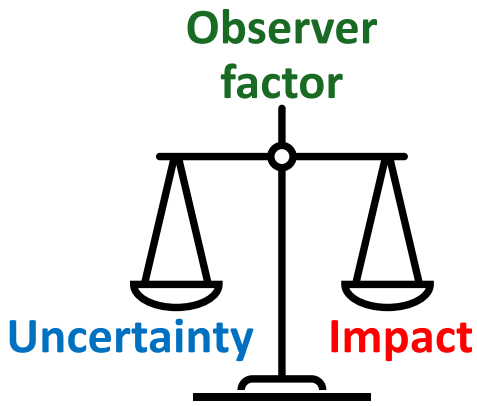
- Periodic measurements.
- The **uncertainty** depends on the measurement period.
- The **impact** depends on the overhead traffic rate.



The Observer Factor

$$\Delta M \cdot \Delta P \geq \eta$$

Uncertainty Impact Observer factor

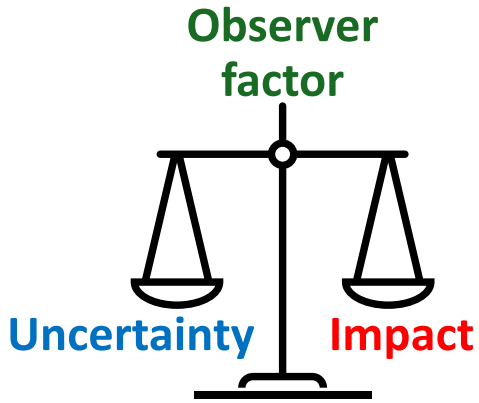


The **observer factor**: the number of overhead bits per measurement period [per flow].

The Observer Factor in Practice

The observer factor in 3 measurement methods, based on 3 open source code repositories used in our evaluation.

Measurement Method	Observer Factor [bytes per measurement period]
Active – CCM [1]	**101**
Passive – gNMI [2]	**204**
In-situ – IOAM [3]	**80**



[1] Active measurement using periodic IEEE 802.1ag Continuity Check Messages (CCM).
https://github.com/vnrick/dot1ag-utils
[2] Passive measurement using local counters and streaming telemetry using gNMI. Our analysis used a Stratum/BMv2 switch.
https://github.com/stratum/stratum
[3] In-situ measurement using In-situ OAM (IOAM) [RFC 9197]. Assuming a 3-hop network, with 8 overhead bytes per hop, and an IPv6 tunnel.
https://github.com/Advanced-Observability/ioam-linux-kernel

The Observer Factor in Practice – Example

- A→B is monitored using a periodic measurement.
- We want to know that **time** at which A→B fails.
- **Uncertainty** = measurement period.

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Uncertainty **Impact** **Observer factor**

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$$\Delta M \cdot \Delta P \geq \eta$$

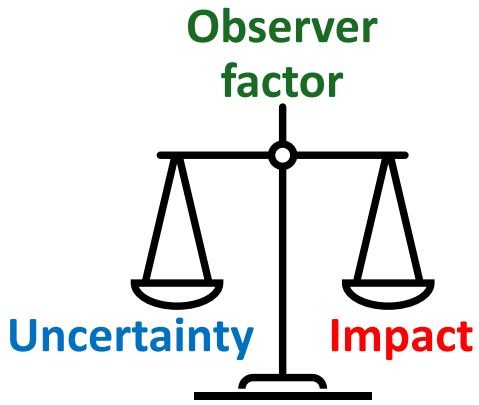
Uncertainty **Impact** **Observer factor**

Given the desired uncertainty, we can estimate the impact of each of the three methods above by:

Impact ≥ **Observer factor** / **Uncertainty**

The Observer Factor in Practice

The observer factor allows an apples-to-apples comparison between different measurement methods.

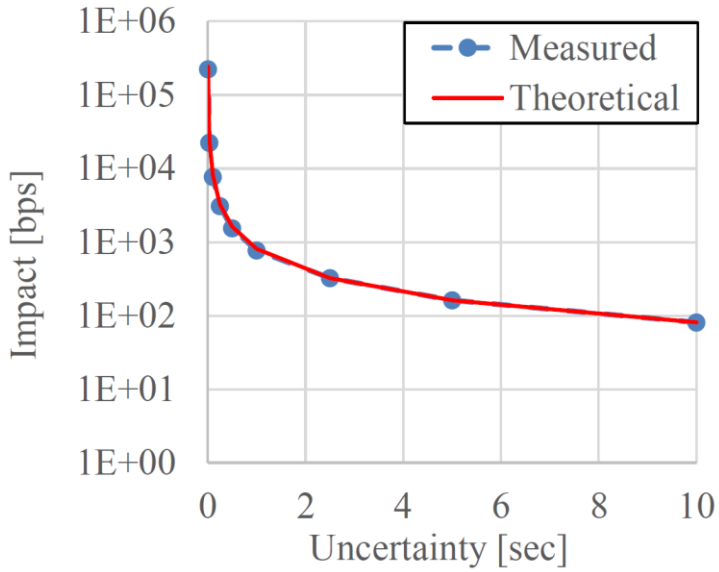


Evaluating the Uncertainty Relation

Our evaluation used 3 open source code repositories, implementing 3 measurement protocols.

Measured vs. theoretical of [1].

The theoretical curve is defined by the uncertainty relation: $\Delta P = \eta / \Delta M$



$$\Delta M \cdot \Delta P \geq \eta$$

Uncertainty Impact Observer factor

[1] Active measurement using periodic IEEE 802.1ag Continuity Check Messages (CCM). https://github.com/vnrick/dot1ag-utils

Conclusion

The observer effect in networks:

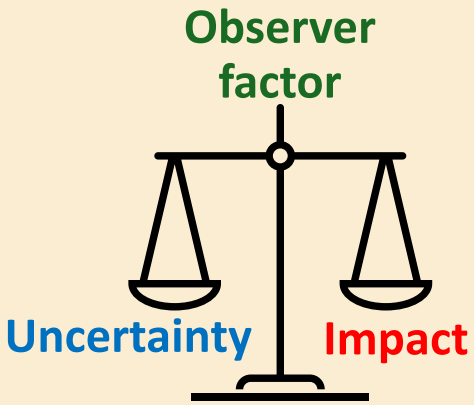
The act of measuring the performance of a network affects the network's performance.

$$\Delta M \cdot \Delta P \geq \eta$$

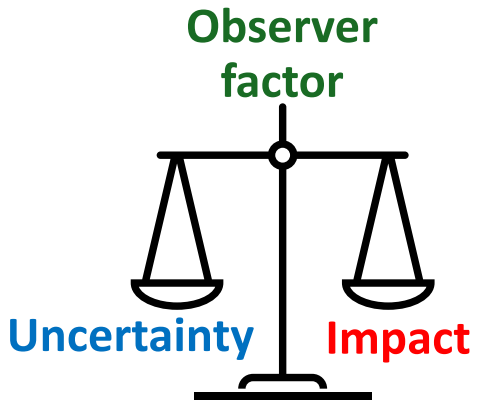
Uncertainty Impact Observer factor

The observer factor:

- A practical metric of the overhead caused by the measurement.
- The observer factor is an important property of every existing / future measurement method.



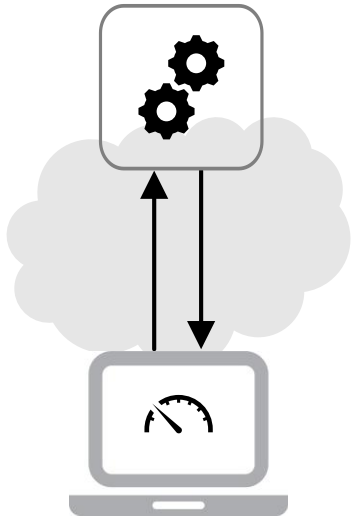
Thanks!



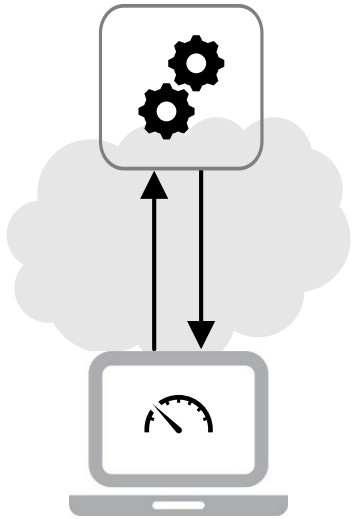
Example: Speed Test

An example of the observer effect:

Running a speed test affects the performance of other applications running in the background.



Example: Speed Test



An example of the observer effect:

Running a speed test affects the performance of other applications running in the background.

An example not related to the observer effect:

Some systems are *designed* to improve their performance under tests.

- “Internet magically gets faster when opening speedtest?” [1]
- “Internet speed goes up if you run a speed test” [2]

[1] https://news.ycombinator.com/item?id=31062799
[2] https://www.thestudentroom.co.uk/showthread.php?t=5205408

References

[1] T. Mizrahi, M. Schapira, and Y. Moses, “The observer effect in computer networks”, ACM Applied Networking Research Workshop (ANRW), https://dl.acm.org/doi/10.1145/3673422.3674894, 2024.

[2] T. Mizrahi, M. Schapira, and Y. Moses, “The observer effect in computer networks”, extended version, ArXiv 2406.09093, https://arxiv.org/abs/2406.09093, 2024.