LARN
Latency- and Resilience-Aware Networking

X-Lap: A Systems Approach for Cross-Layer Profiling and Latency Analysis for Cyber-Physical Networks

RTN 2017

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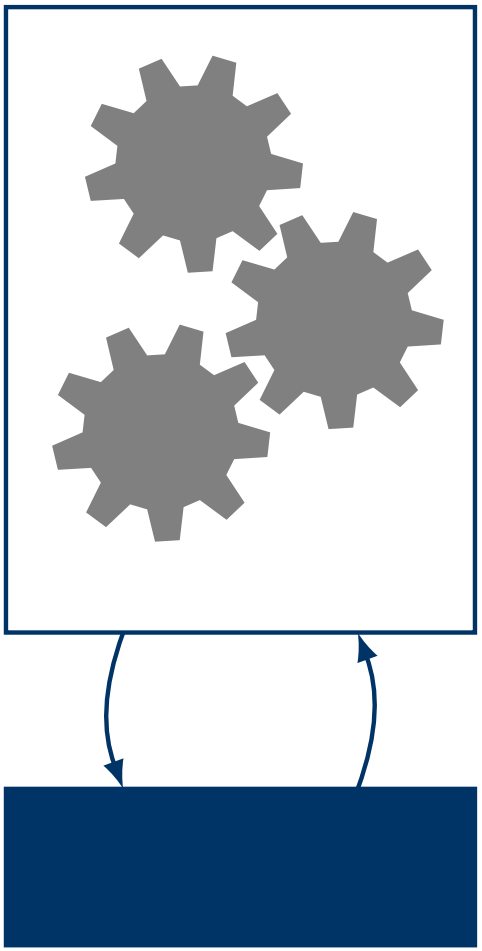
June 27, 2017

Cyber-Physical Networks (CPNs)



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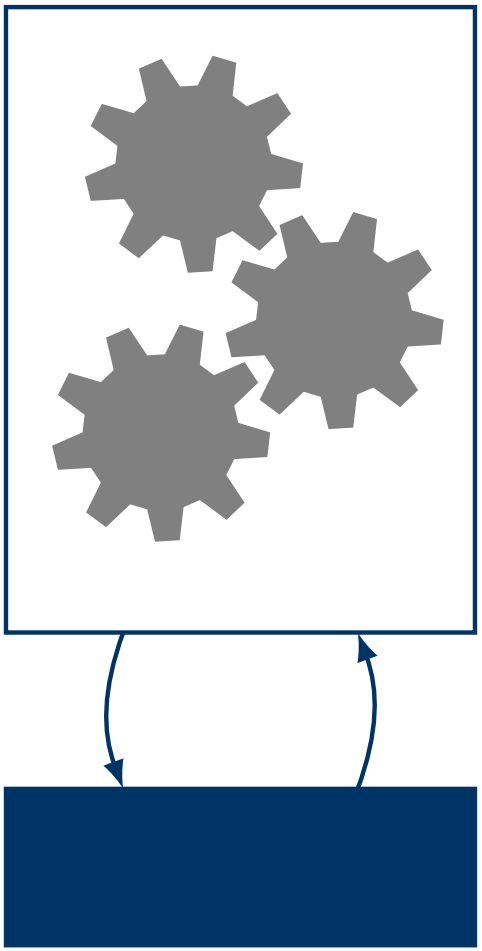

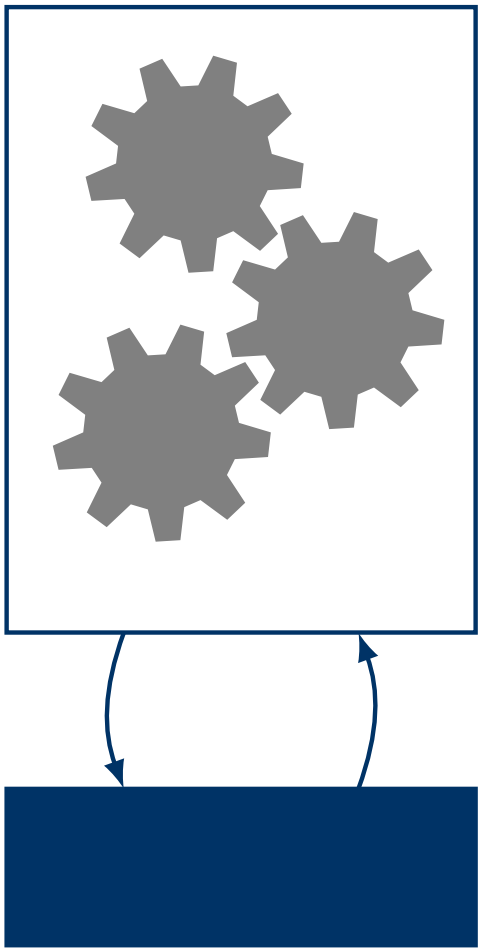

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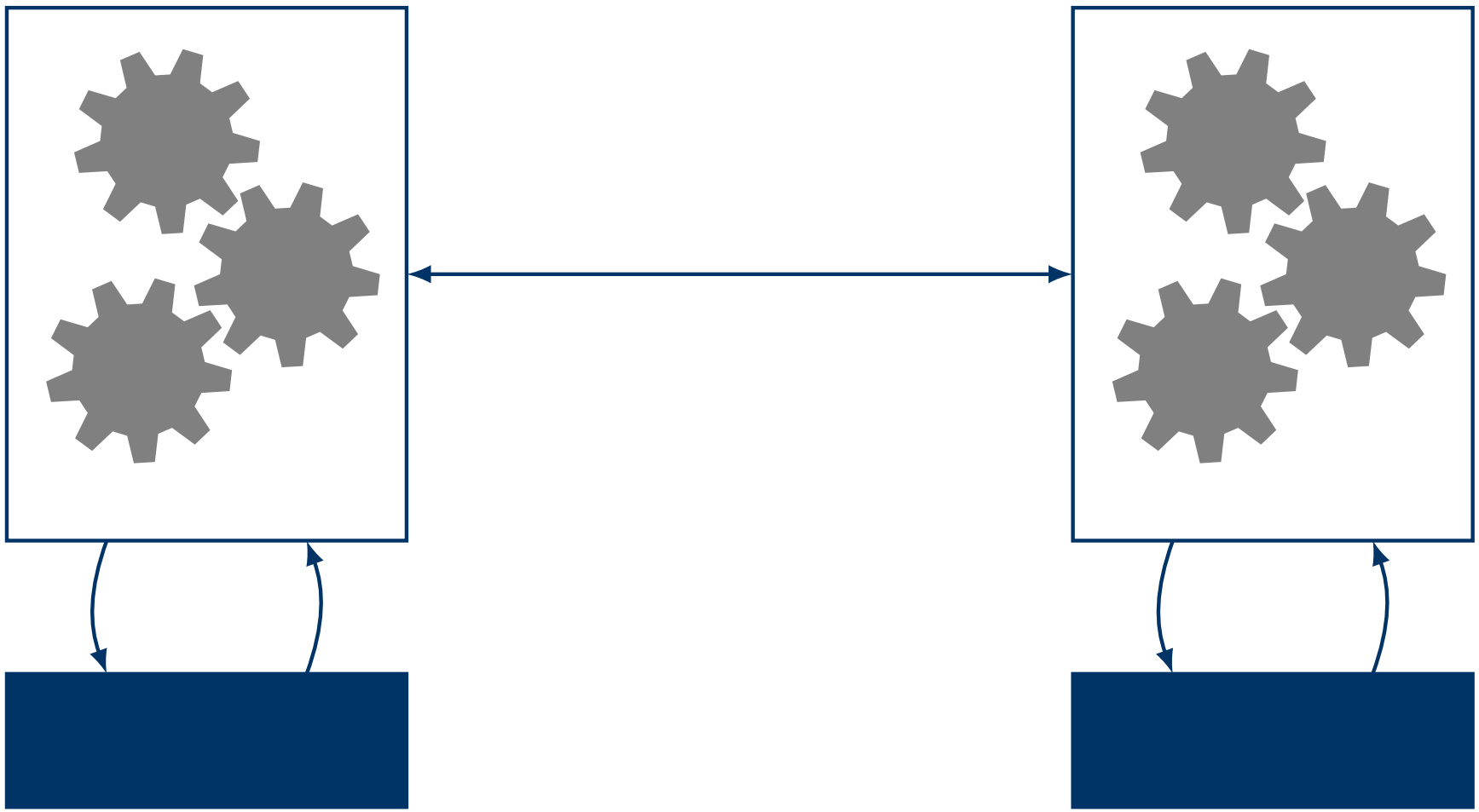

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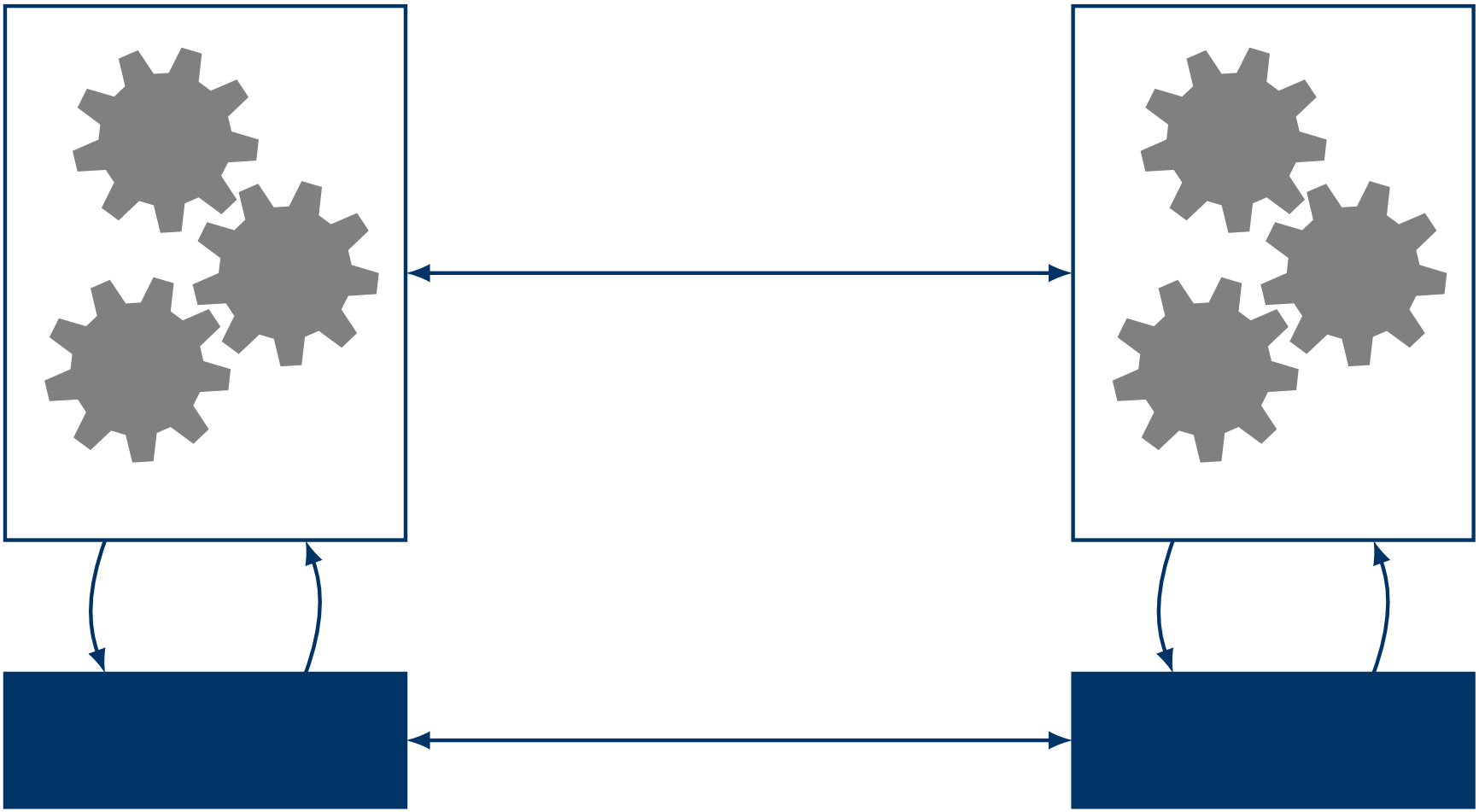

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Single-Host Evaluation Tools

- Local evaluation
- Network-oblivious

Network Evaluation Tools

- Network protocol evaluation
- Abstract from host-related delays

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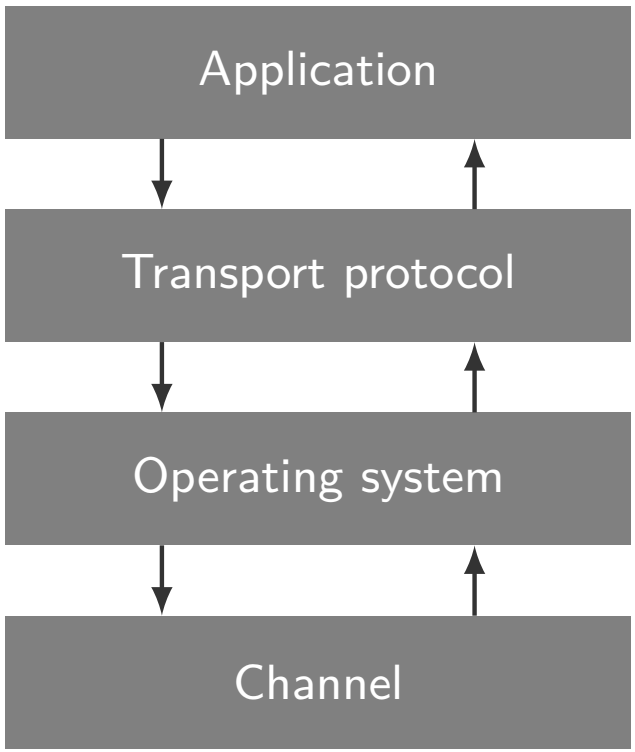
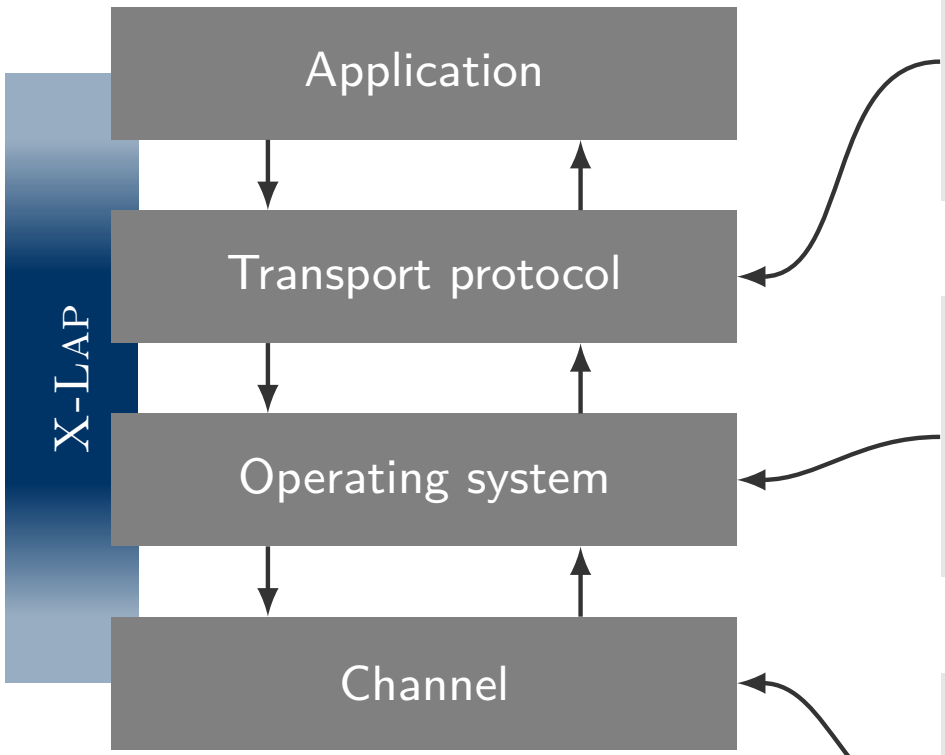
Need for Cross-Layer-Analysis of communication stacks

Outline


Application
Transport protocol
Operating system
Channel



- Packet creation
- Error correction
- ...

- Inter-process communication (IPC)
- Resource management
- ...

- Transmission delay
- Propagation delay
- ...

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Run-time evaluation

- Timestamping functions
- $\Rightarrow$ Timestamps
- C code

Off-line analysis

- Data analysis
- $\Rightarrow$ Latency and jitter
- Python code

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Run-time evaluation

- Timestamping functions
- $\Rightarrow$ Timestamps
- C code

- Trace every packet
- Minimize run-time interference
- Embedded into protocol source code

Off-line analysis

- Data analysis
- $\Rightarrow$ Latency and jitter
- Python code

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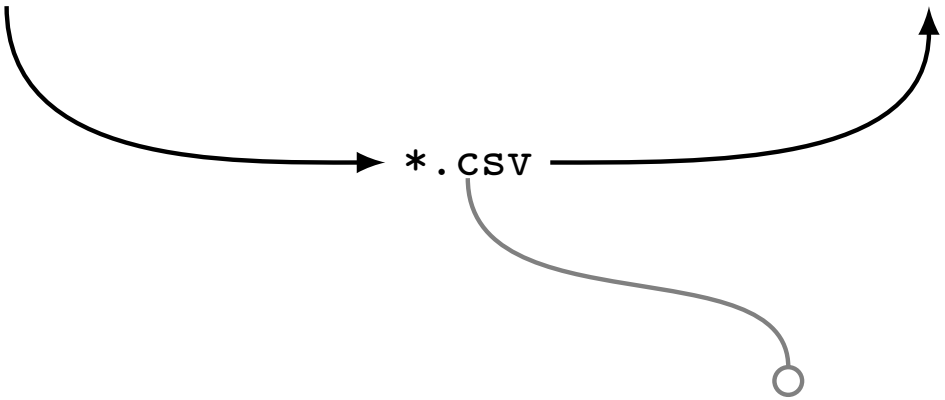
Run-time evaluation

- Timestamping functions
- ⇒ Timestamps
- C code

Off-line analysis

- Data analysis
- ⇒ Latency and jitter
- Python code



- Collect traces
- Combine trace data

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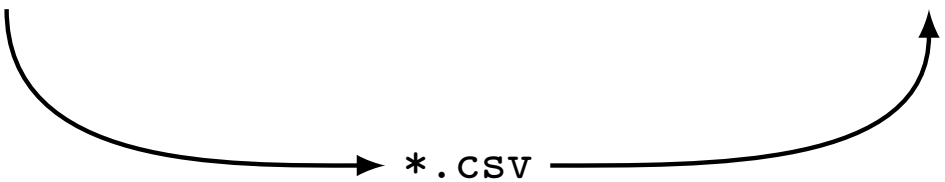
Run-time evaluation

- Timestamping functions
- ⇒ Timestamps
- C code

Off-line analysis

- Data analysis
- ⇒ Latency and jitter
- Python code



- Single-packet traces
- Jitter amongst packets
- Outlier analysis
- Correlation analysis

UDP

- Data integrity checks
- No timeliness guarantees

TCP

- Error control
- No timeliness guarantees

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UDP

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- No timeliness guarantees

TCP

- Error control
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Not suitable for reliable real-time networks

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UDP

- Data integrity checks
- No timeliness guarantees

TCP

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Not suitable for reliable real-time networks

PRRT

- Error correction
- Latency-awareness

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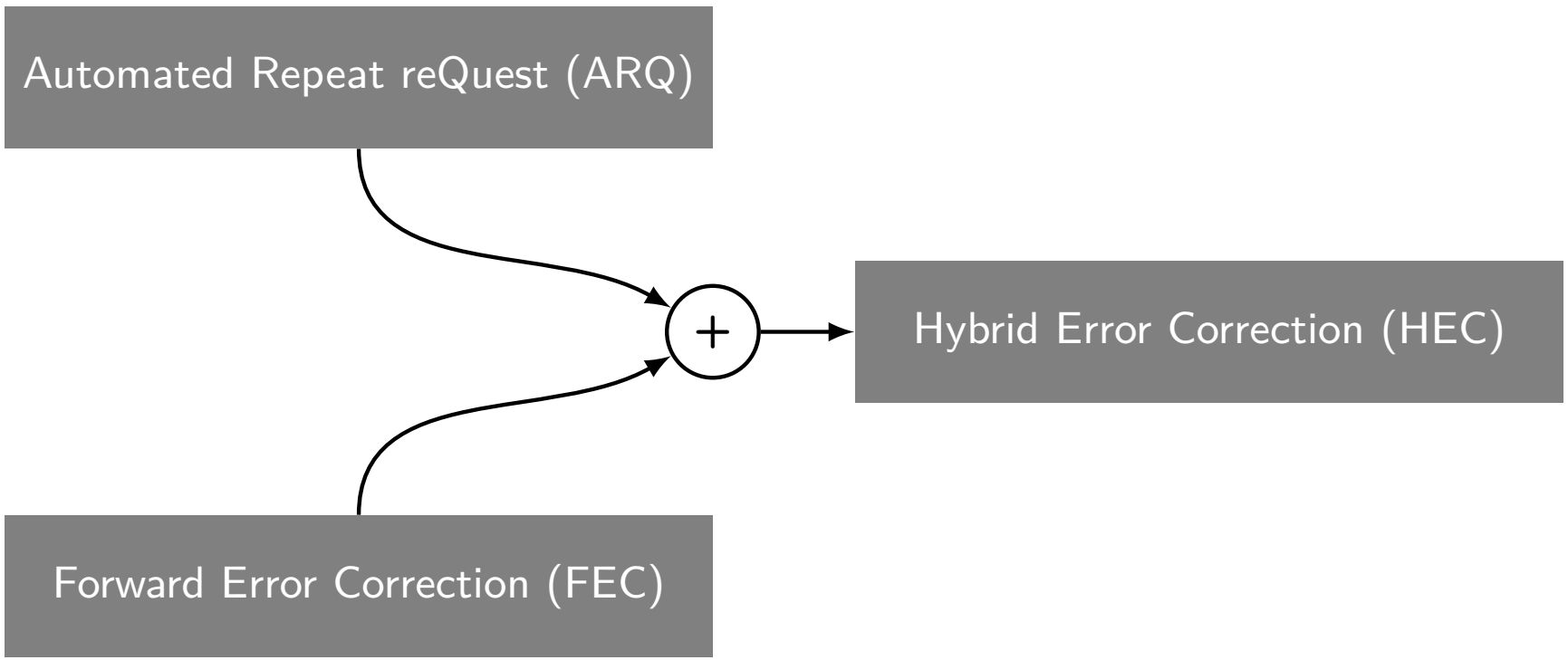
Automated Repeat reQuest (ARQ)

Forward Error Correction (FEC)


Automated Repeat reQuest (ARQ)
+
Hybrid Error Correction (HEC)
Forward Error Correction (FEC)

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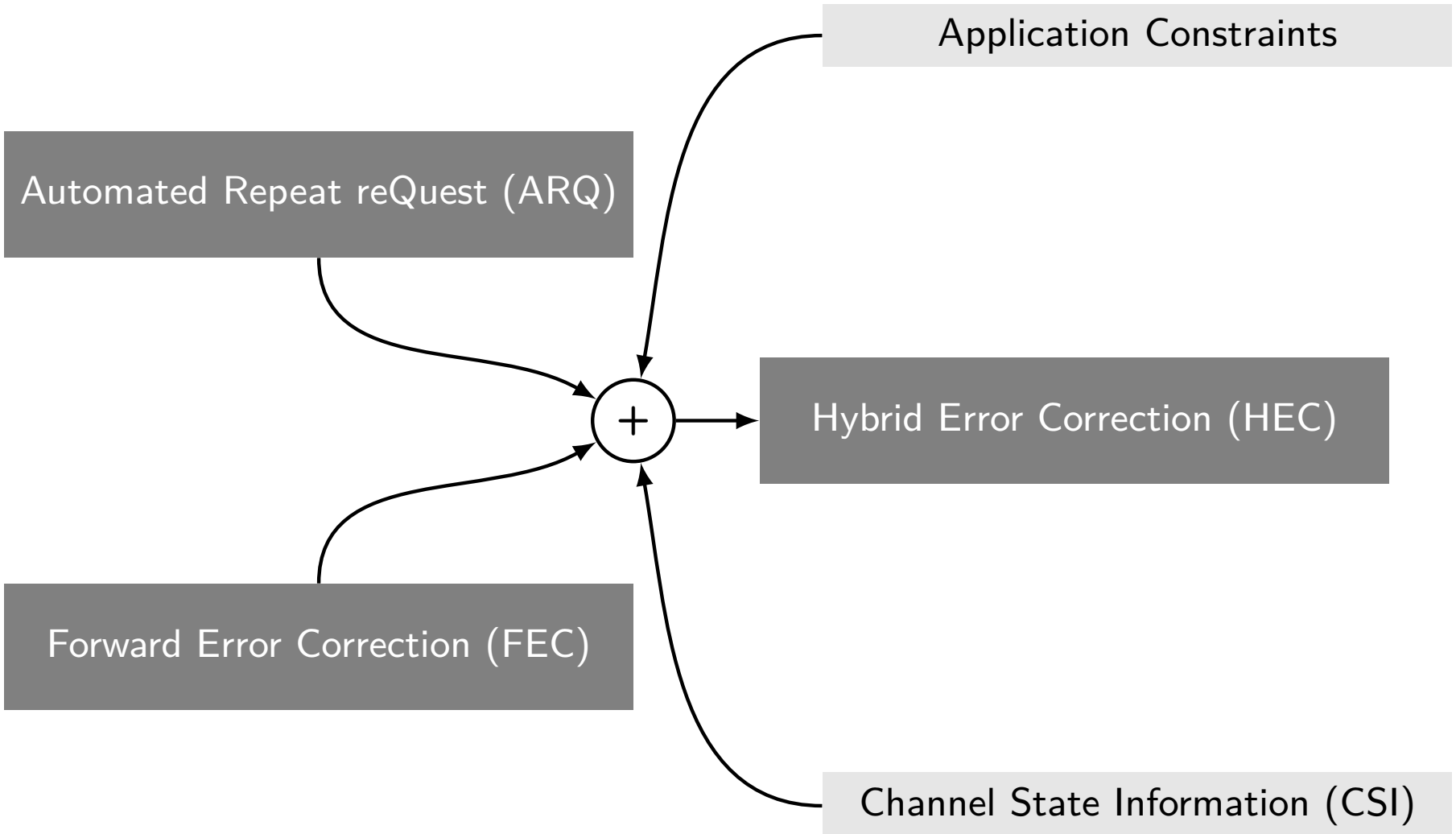
Application Constraints
Automated Repeat reQuest (ARQ)
+
Hybrid Error Correction (HEC)
Forward Error Correction (FEC)
Channel State Information (CSI)

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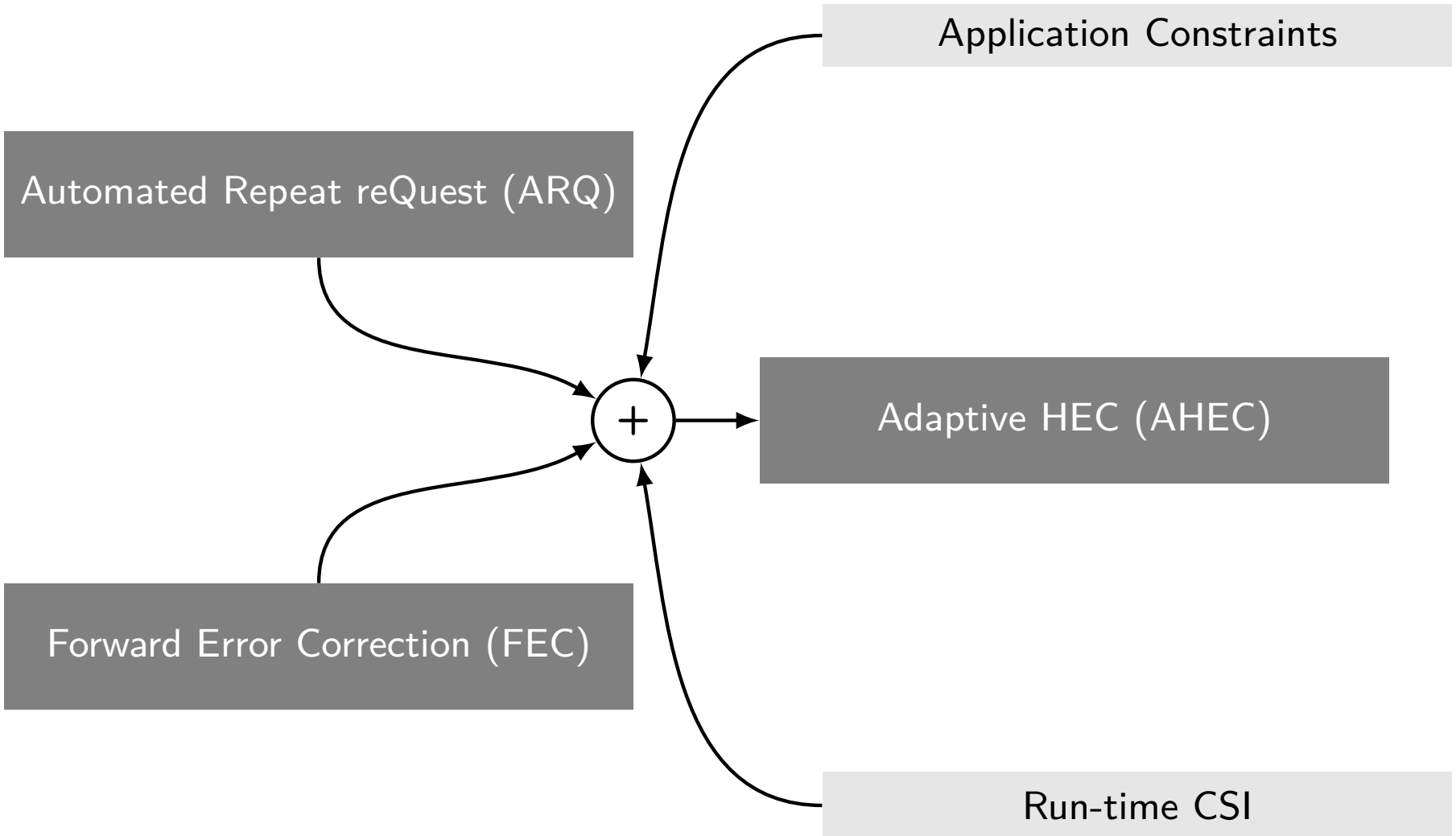
Application Constraints
Automated Repeat reQuest (ARQ)
+
Adaptive HEC (AHEC)
Forward Error Correction (FEC)
Run-time CSI

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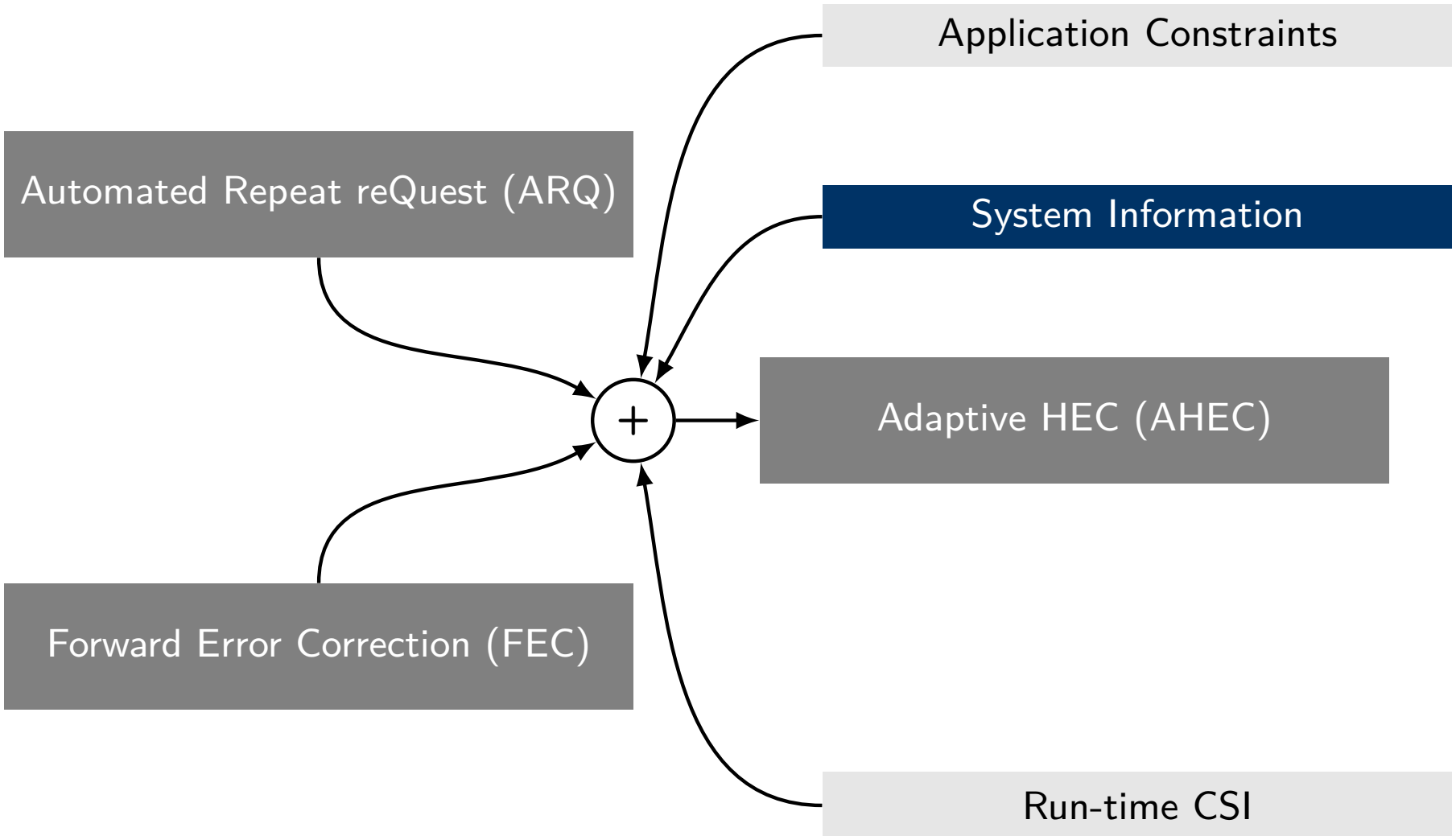
Application Constraints
Automated Repeat reQuest (ARQ)
System Information
+
Adaptive HEC (AHEC)
Forward Error Correction (FEC)
Run-time CSI

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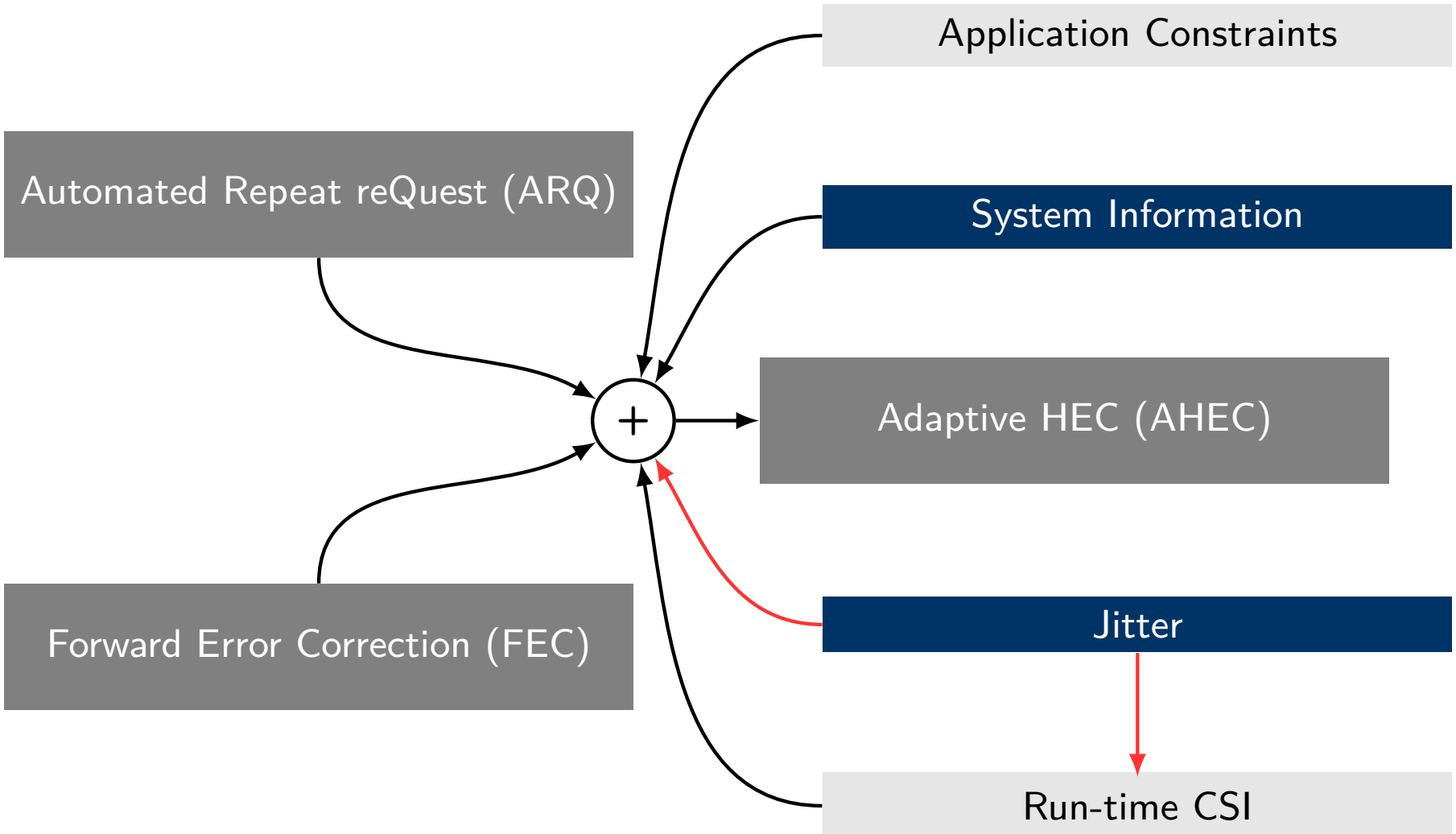
Application Constraints
Automated Repeat reQuest (ARQ)
System Information
+
Adaptive HEC (AHEC)
Forward Error Correction (FEC)
Jitter
Run-time CSI

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Benefits from X-Lap

- Obtain system information
- Analyse jitter

Goals: Latency and jitter ...

- ... avoidance
  - → Eliminate causes of latency and jitter
- ... hiding
  - → Preparatory/Clean-up tasks
  - → Optimise resource management
- ... tolerance
  - → Parameters for AHEC

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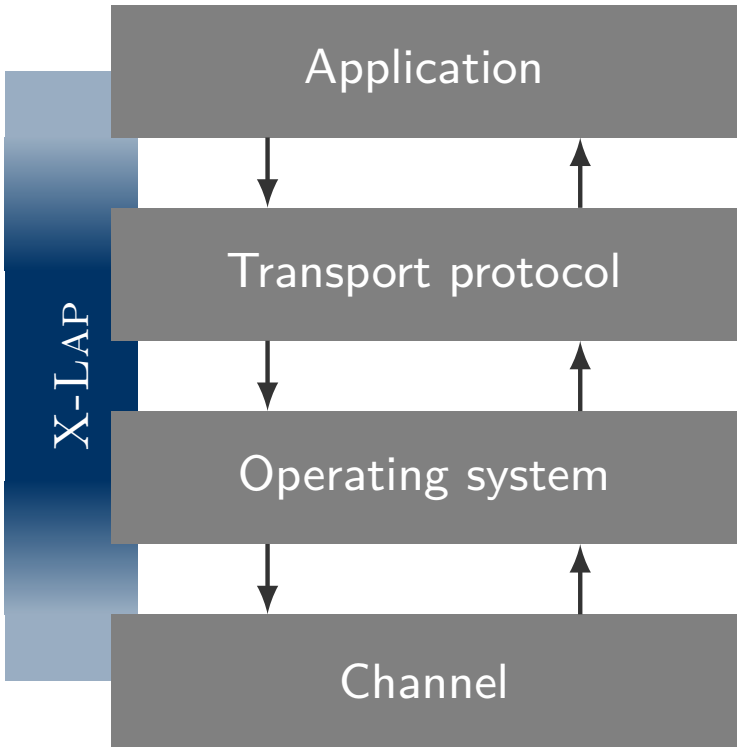
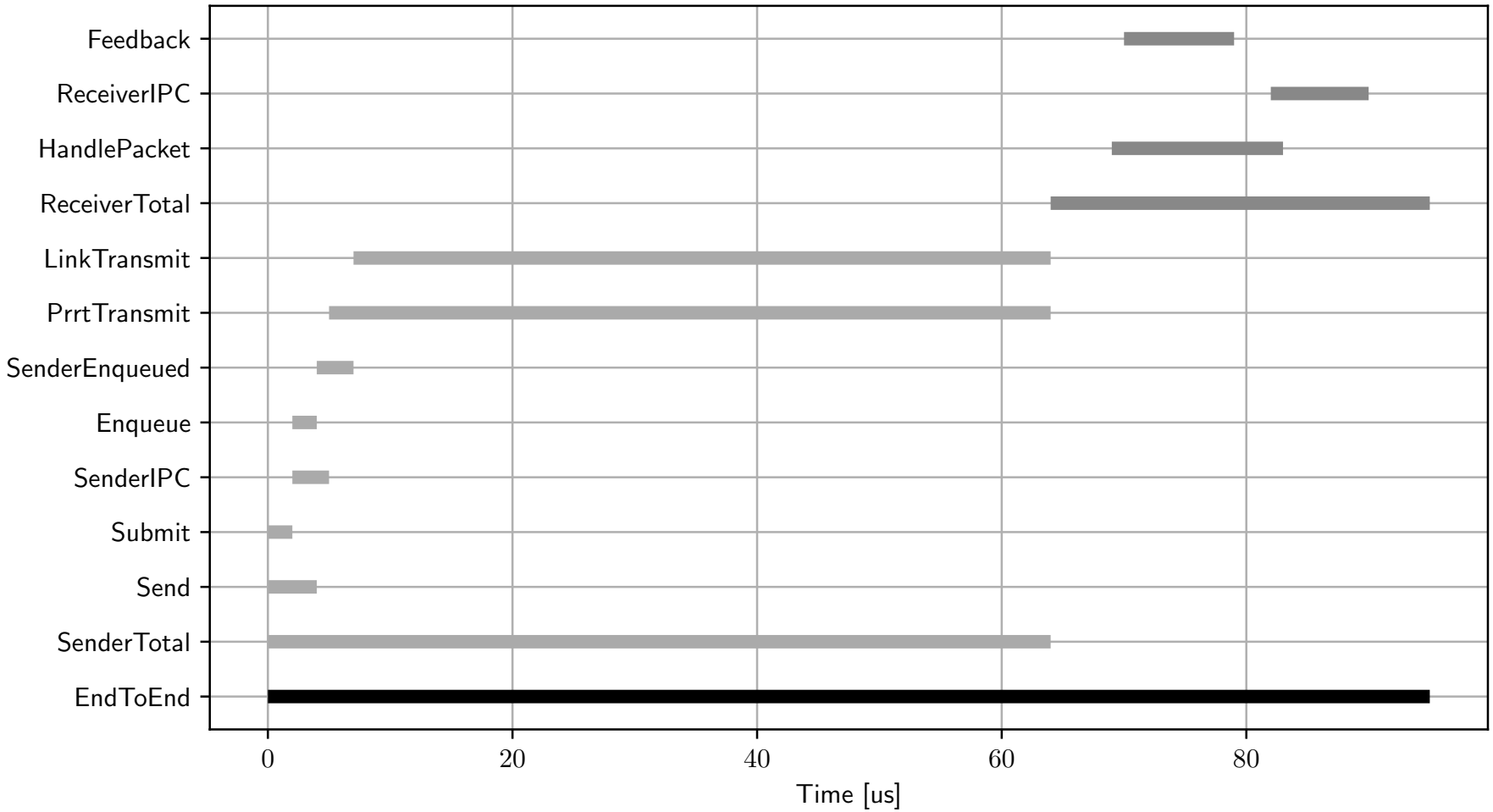
Evaluation focus

- PRRT
- Interaction with OS

Future work

- Application delays
- Network transmission time




Feedback
ReceiverIPC
HandlePacket
ReceiverTotal
LinkTransmit
PrrtTransmit
SenderEnqueued
Enqueue
SenderIPC
Submit
Send
SenderTotal
EndToEnd
0
20
40
60
80
Time [us]

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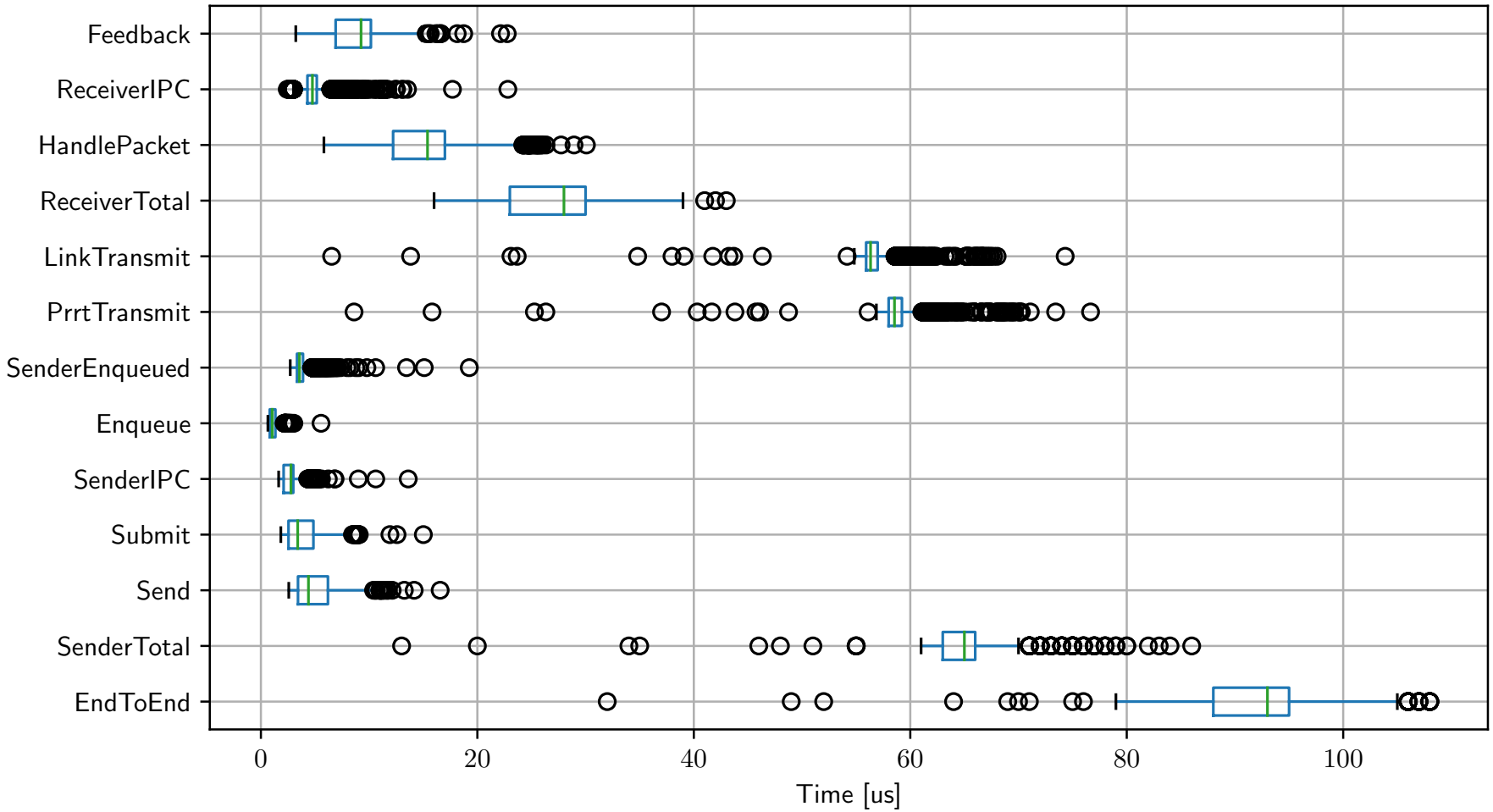
Feedback
ReceiverIPC
HandlePacket
ReceiverTotal
LinkTransmit
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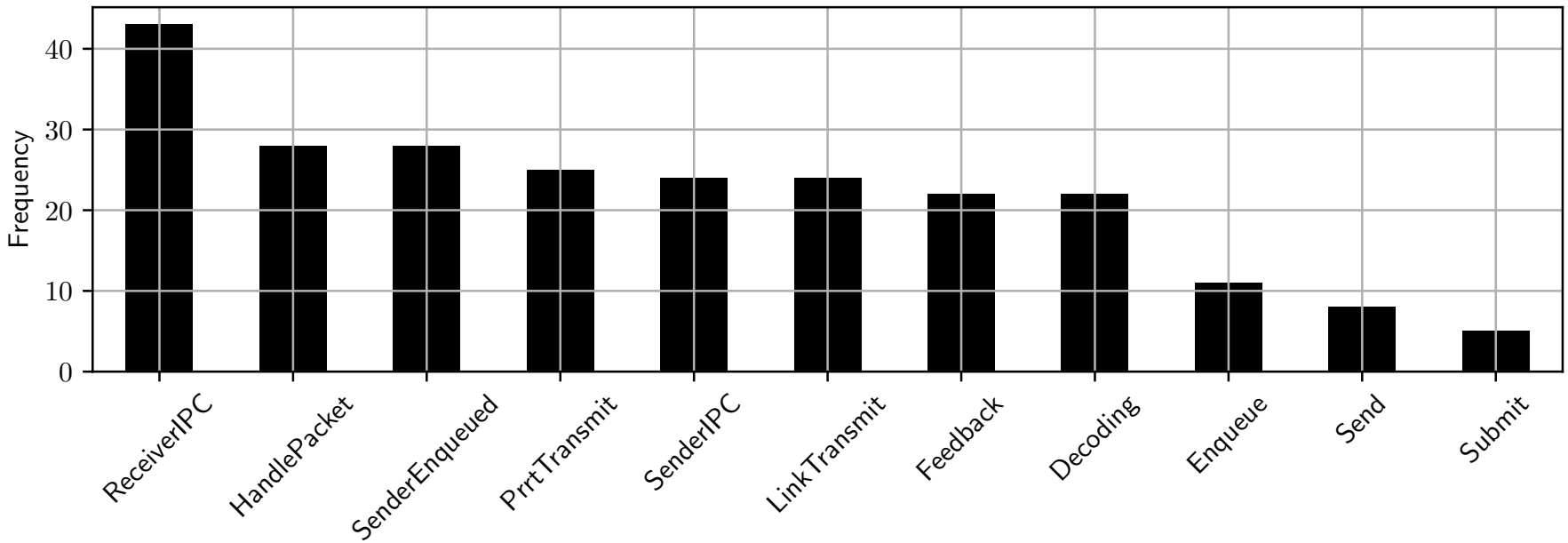
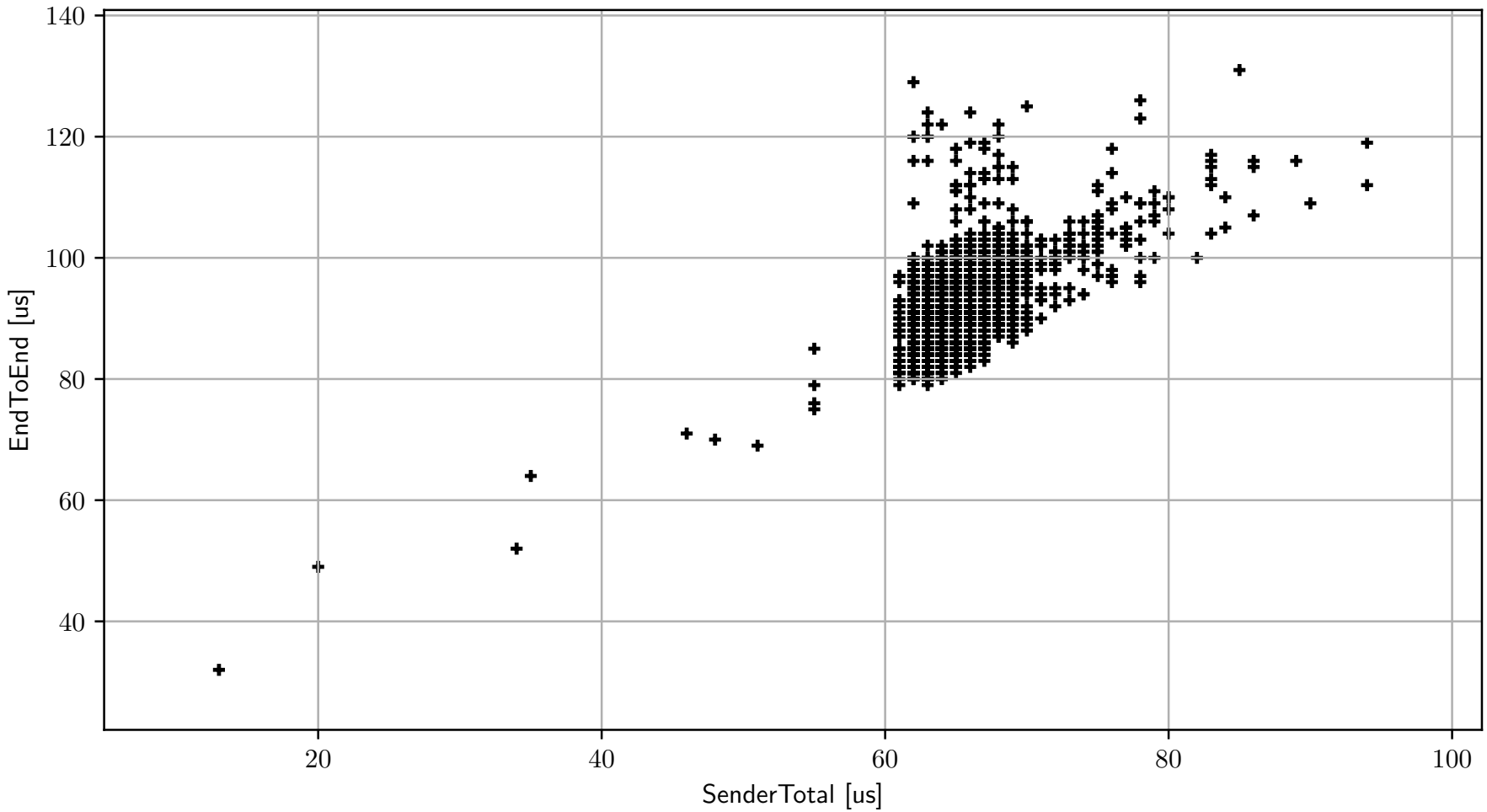
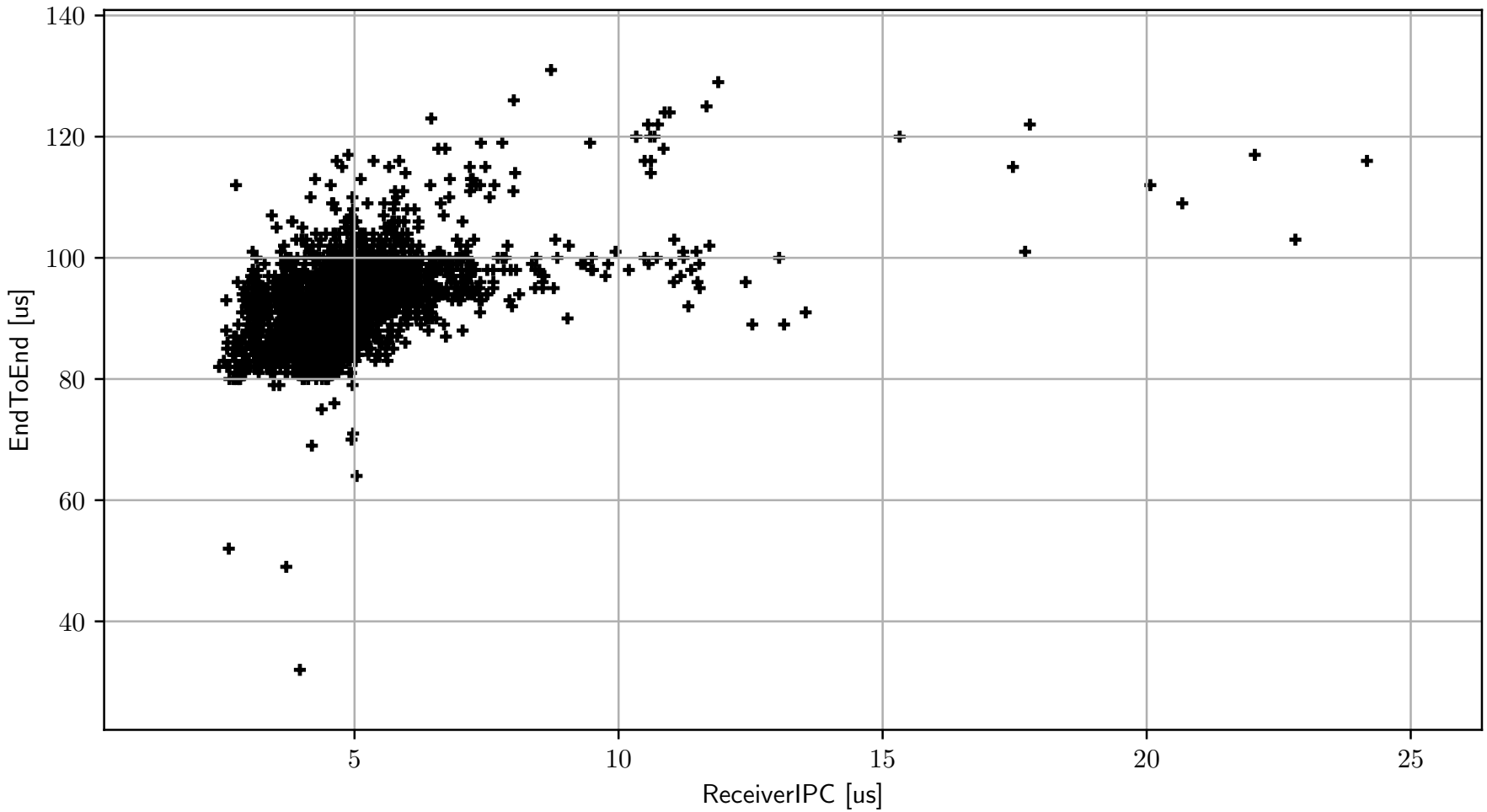
Submit
Send
SenderTotal
EndToEnd
0
20
40
60
80
100
Time [us]


Frequency
0
10
20
30
40
ReceiverIPC
HandlePacket
SenderEnqueued
PrrtTransmit
SenderIPC
LinkTransmit
Feedback
Decoding
Enqueue
Send
Submit


140
120
100
80
60
40
EndToEnd [us]
20
40
60
80
100
SenderTotal [us]


140
120
100
80
60
40
EndToEnd [us]
5
10
15
20
25
ReceiverIPC [us]

X-Lap

- Cross-layer, inter-host timing analysis tool
- Evaluation of real-time network protocols

Source Code available at:
→ `http://xlap.larn.systems`

PRRT Analysis

	Sender	Receiver	Network-related
Latency	`PrrtTransmit`	`SendFeedback`	`LinkTransmit`
Jitter	`SenderEnqueue`	`ReceiverIPC`	`LinkTransmit`

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Thank you for your attention. Questions?