Personal Introduction VSBS@Ilmenau

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Distributed and Operating Systems Group
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Overview

Boris Koldehofe

Since February 2023

- Full Professor @ TU Ilmenau

2020-2023

- Full Professor at University of Groningen

Before:

- Research Associate at TU Darmstadt
- Managing Director of CRC MAKI
- Research Associate at Universität Stuttgart
- …

Research Team:

Soon ~9 researchers distributed over multiple locations:

- Ilmenau (4), Groningen (3), Darmstadt (2)

Research Scope:

- Distributed Systems & Computer Systems
  - E.g. Distributed Data Analytics / Real-Time streaming
- In-Network Computing
  - High Performance Middleware, Energy Efficiency
- Enforcing Non-Functional properties
  - Security engineering , Reliability

Data Driven Applications

Nowadays everywhere!

- Autonomous driving, smart factories, smart cities, telemedicine, and many more

MAPE loop of IoT services:

- **M**onitor and **A**nalyze “Things”
- **P**lan and **E**xecute Processes

Insights into data key to adapt applications

- Billions of things
- Exabytes of context knowledge

But Performance and Low Latency is not straight forward!

Approach: In-Network Computing

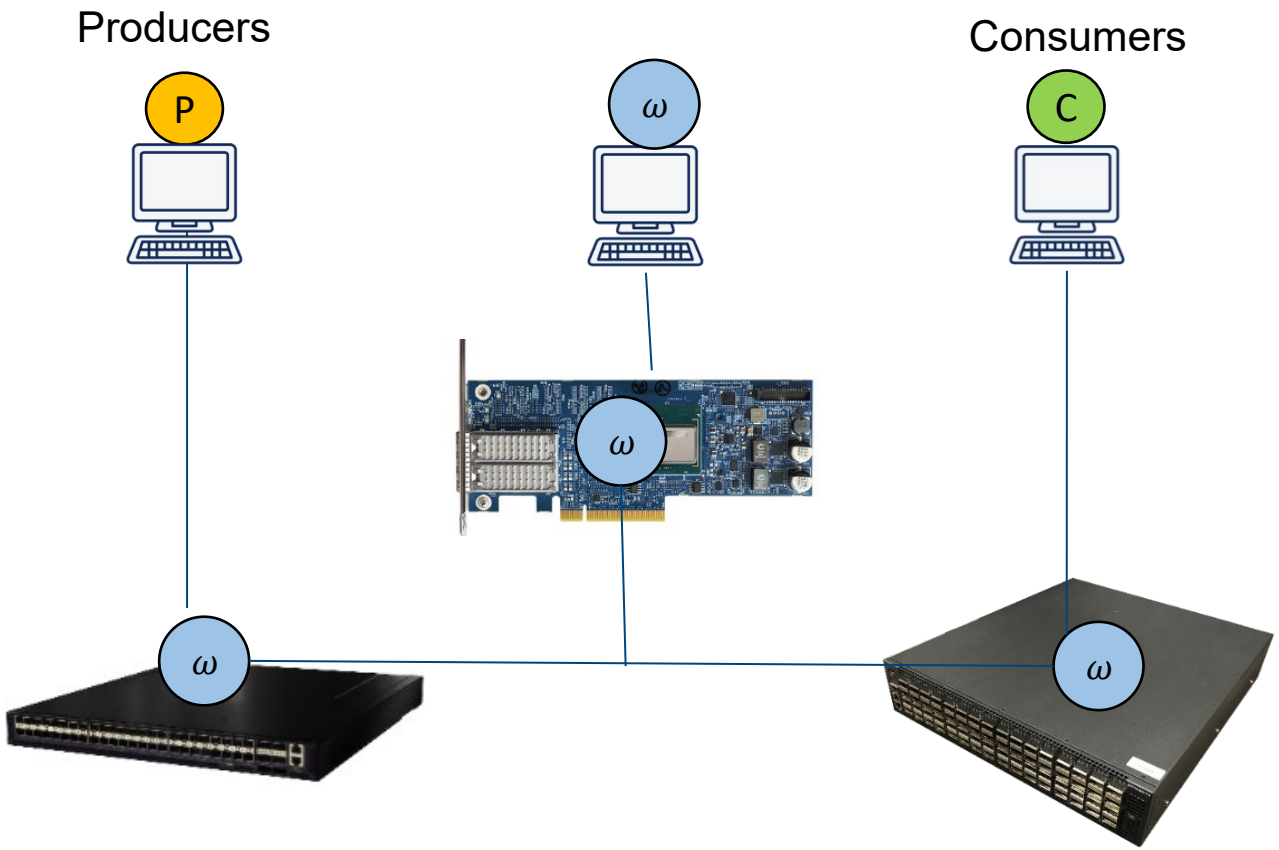
Idea enable computations on the data path and minimize data movement

Traditionally,

- Packet header processing,
  - e.g., routing, firewall, packet classification, load balancing, deep packet inspection

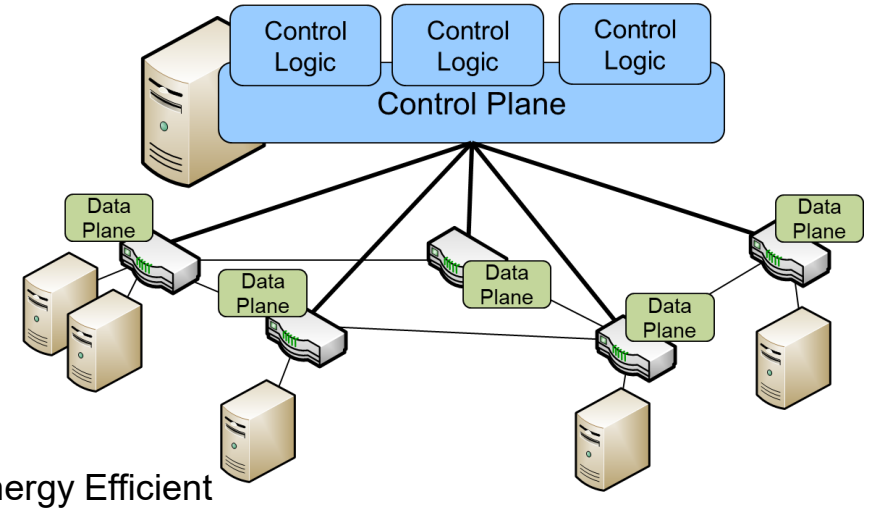
But high potential to enhance distributed computing and middleware services

Note: Control plane of INP is often referred to as a Network Operating System (NOS)



Developments: In-Network Computing

Benefit from Variety and Evolution on Programable hardware and new networking paradigms



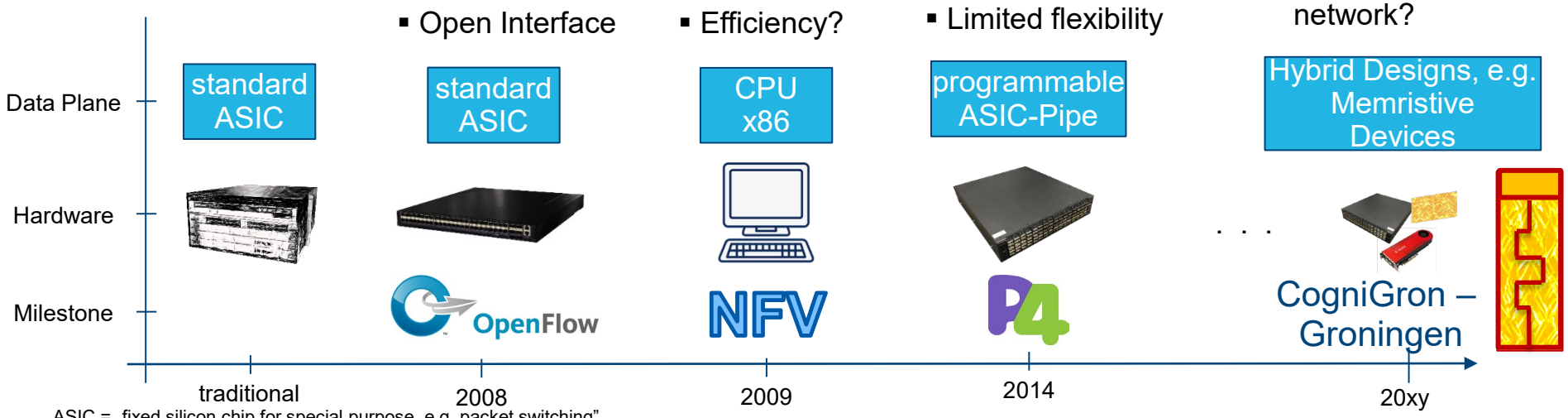
- "Blackbox"
- Vendor-lock

- "Blackbox" → "Whitebox"
- Software-defined Networking
- Open Interface

- Traditional compute resources
- Performance?
- Efficiency?

- Programmable ASIC for packet processing
- Very high bandwidth
- Limited flexibility

- Energy Efficient Switching?
- Computational Intelligence inside the network?



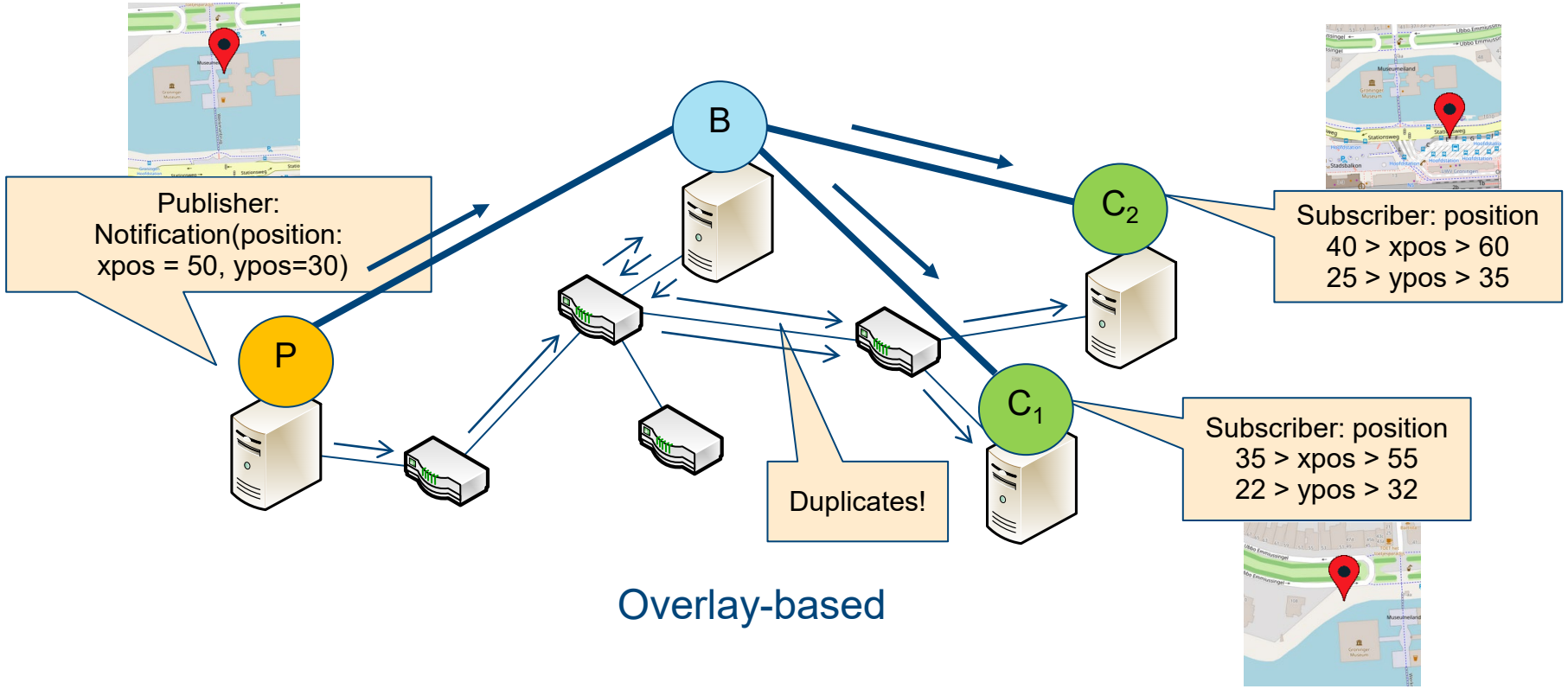
ASIC = „fixed silicon chip for special purpose, e.g. packet switching"

Application to Middleware

Example: High Performance Publish/Subscribe

Reduce the overhead:

- Message duplications
- Matching subscriptions at the hardware



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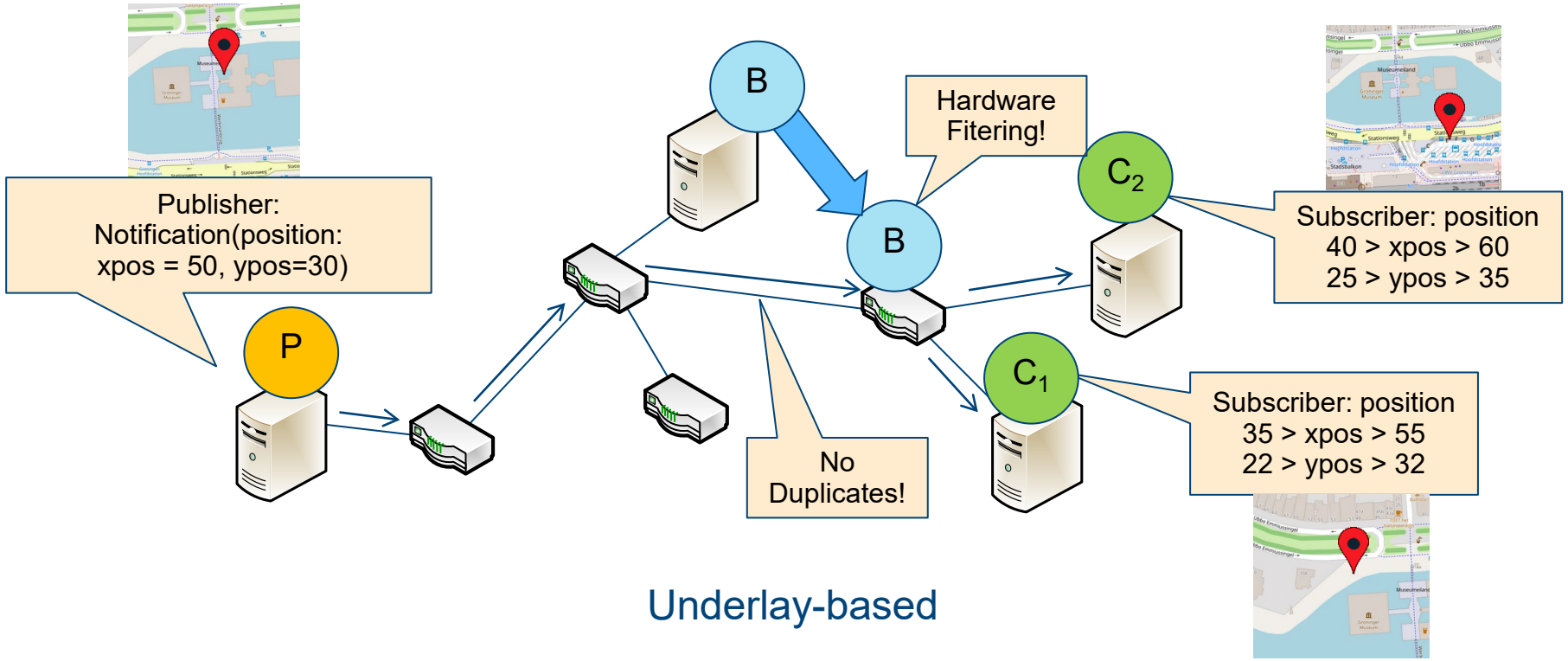


Everything on Performance?

Not really!

Data movements are the cause for high energy efficiency!

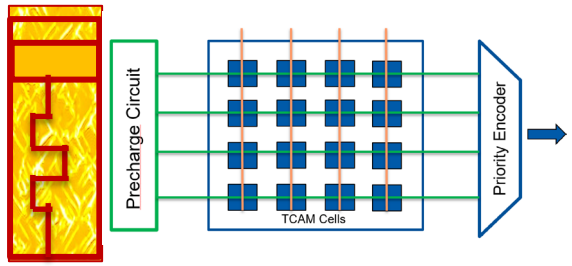
Moving to sustainable computing components!

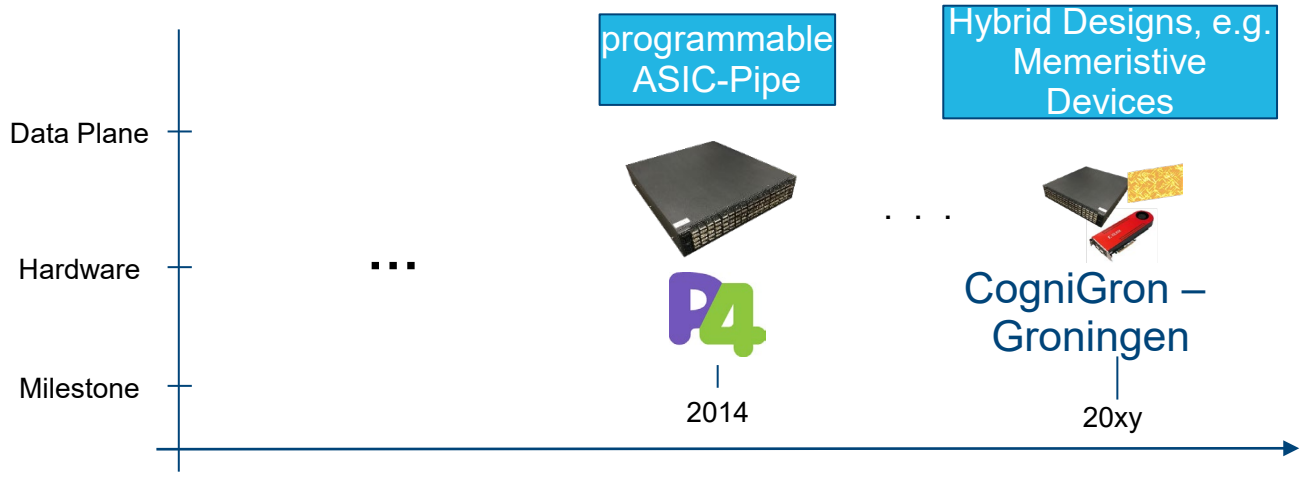
- Programmable ASIC for packet processing
- Very high bandwidth
- Limited flexibility

- Energy Efficient Switching?
- Computational Intelligence inside the network?

Recent example

- **TCA*m*M^{CogniGron}: Energy Efficient Memristor-Based TCAM for Match-Action Processing**





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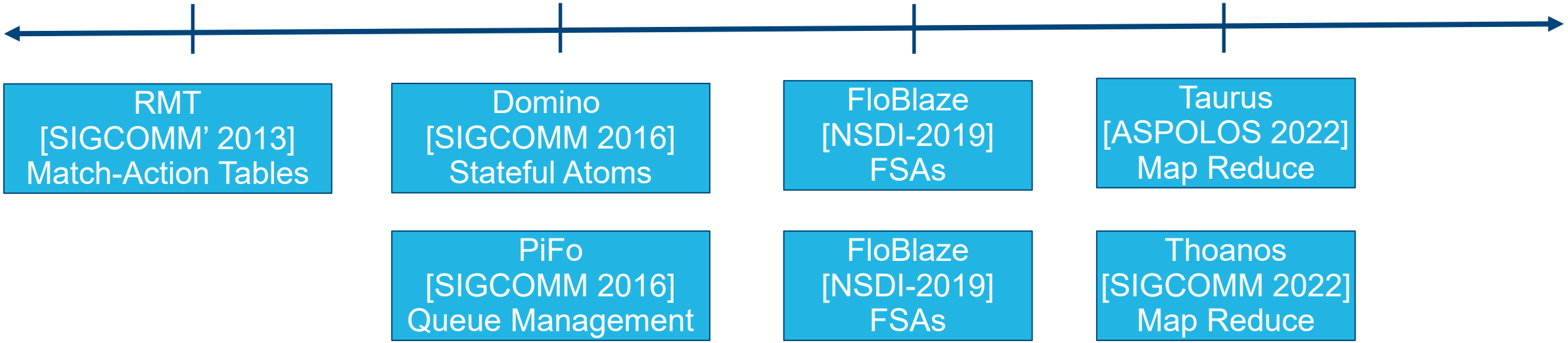
Interesting Approaches in INP for Data Driven Applications

Networking Community is working on many abstractions for Stateful INP

Challenge: understand practicality and applicability in Middleware services



Adapted from Vishal Shrivastav presentation at SIGCOMM

But also very interesting work in distributed computing!

- E.g. " P4xos: Consensus as a Network Service", IEEE/ACM Transactions on Networking, 2020.

Conclusions

In-Network Computing is a fundamental but challenging paradigm to enhance performance

“Understand better of distributed computing principles based on In-network computing”

Distributed Adaptation Methods	Programming Models	Programable Hardware

Many more research topics:

- **Distributed Stream Processing**
- **Time Sensitive Networking**
- **Privacy-awareness**
- **Distributed AI**
- **…**

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Exemplary Findings/ Research

High Performance Middleware, e.g., Publish/Subscribe, Stream Processing, …

In-Network Parallelization/Balancing for High Performance Data Analytics

In-Network Monitoring

Energy-efficient In-Network Computing Components

Performance Benchmarking of Data Analytics Functions

Quality Monitoring of Data Streaming Applications

Privacy and Security Enforcement of Communication Middleware

Time Sensitive Networking

Saad Saleh, Boris Koldehofe. **On Memristors for Enabling Energy Efficient and Enhanced Cognitive Network Functions.** In IEEE Access, 34 pages, IEEE 2022.

Ralf Kundel and Fridolin Siegmund and Rhaban Hark and Amr Rizk and Boris Koldehofe. **Network Testing Utilizing Programmable Networking Hardware.** IEEE Communications Magazine, 7 pages, IEEE 2022.

Manisha Luthra, Boris Koldehofe, Niels Danger, **Pascal Weisenburger, Guido Salvaneschi, and Ioannis Stavrakakis. TCEP: Transitions in Operator Placement to Adapt to Dynamic Network Environments.** In Journal of Computer and Systems Sciences (JCSS), Special Issue on Algorithmic Theory of Dynamic Networks and its Applications, vol. 122, pp. 94–125, Elsevier 2021.

Ralf Kundel, Leonhard Nobach, Jeremias Blendin, Hans-Jörg Kolbe, Georg Schyguda, Vladimir Gurevich, Boris Koldehofe, Ralf Steinmetz. **OpenBNG: Central Office Network Functions on Programmable Data Plane Hardware.** In International Journal of Network Management, Vol. 31(e2134), 25 pages, Wiley 2021.

Sukanya Bowmik, Adnan Tariq, Boris Koldehofe, Thomas Kohler, Frank Dürr, Kurt Rothermel. **High Performance Publish/Subscribe Middleware in Software-defined Networks.** IEEE Transactions on Networking (ToN), vol. 25(3), pp. 1501–1516, 2017. IEEE.

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