Decentralized Information Flow Control for ROS2

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Himanshu Kumar *(Indian Institute of Science)*
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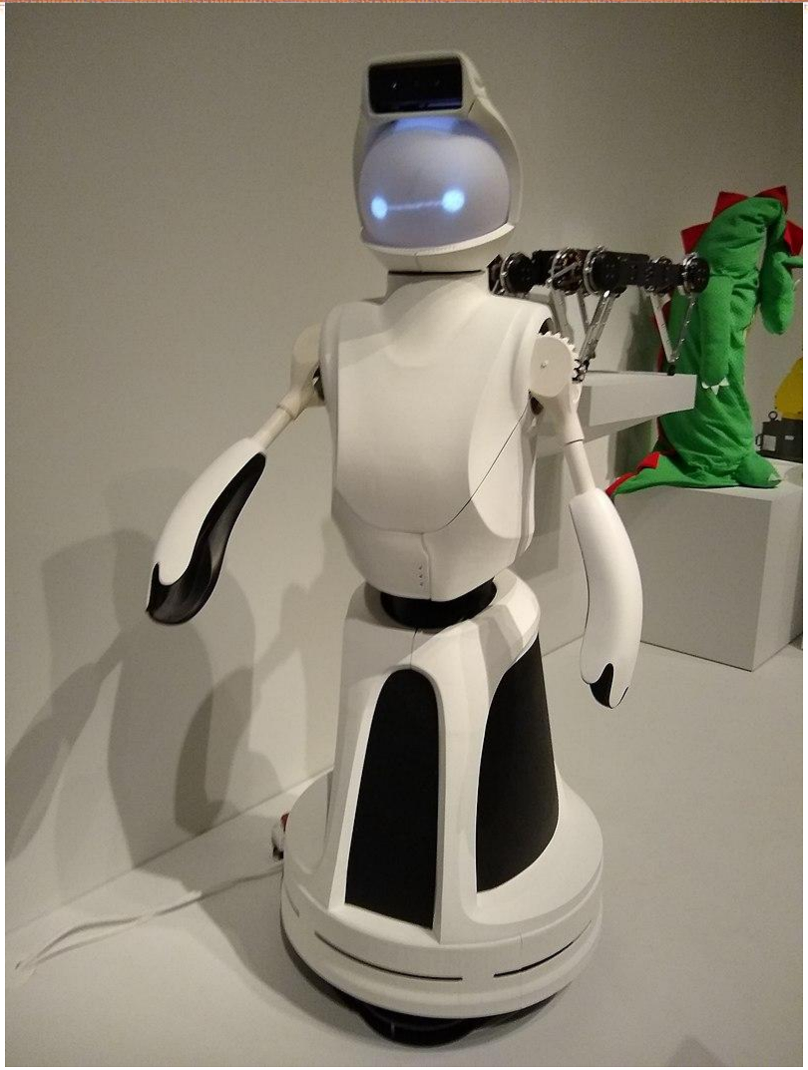
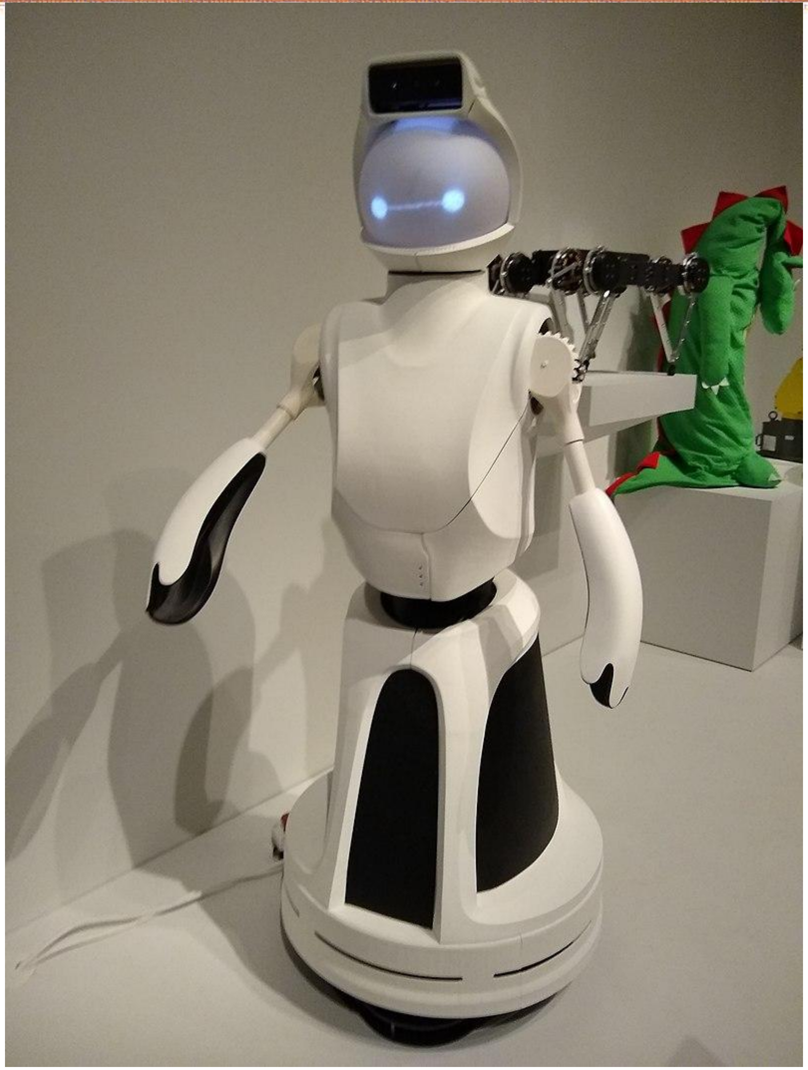
INDIAN INSTITUTE OF SCIENCE
भारतीय विज्ञान संस्थान

** - work done while at IISc*



Personal Assistance Robots

Fleets of Warehouse Robots
(Image Credit: User:Geni, CC-BY-SA 4.0)



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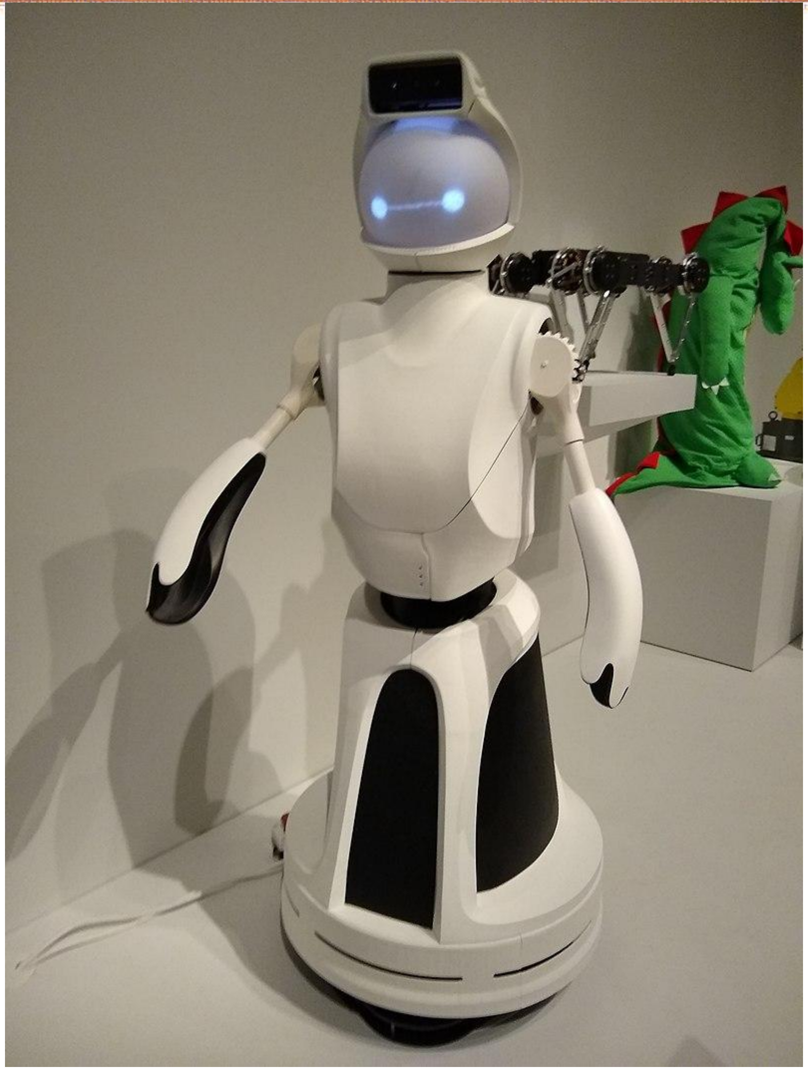

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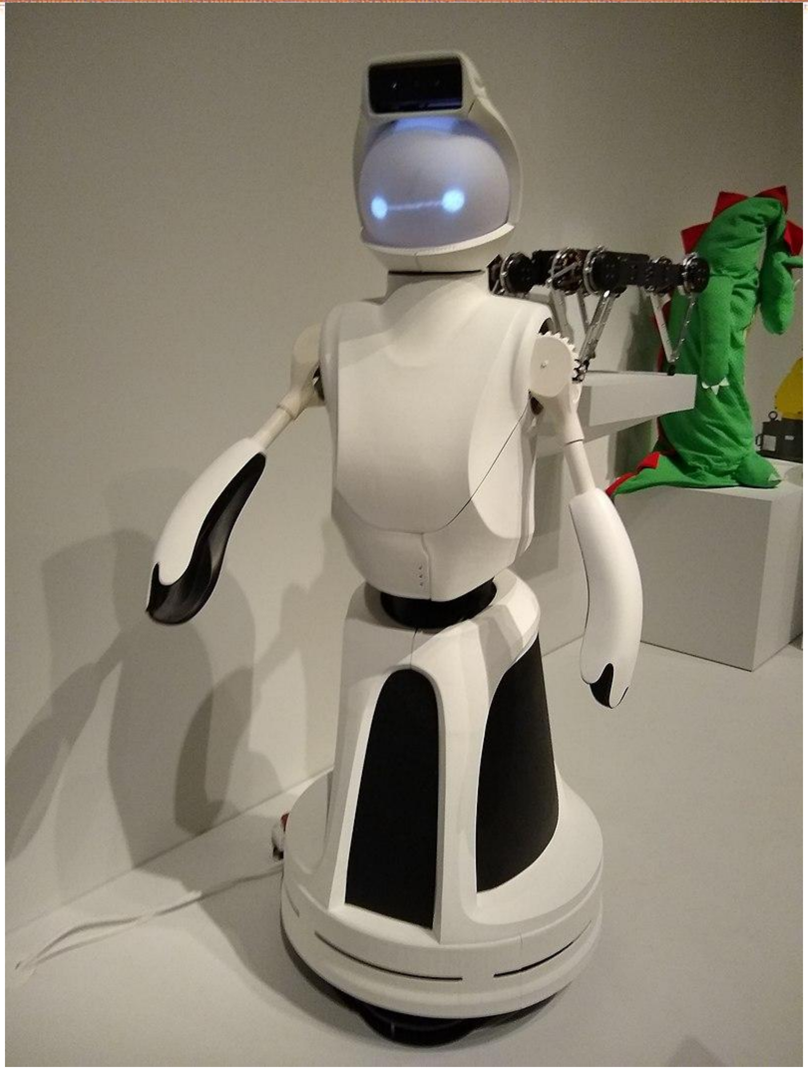

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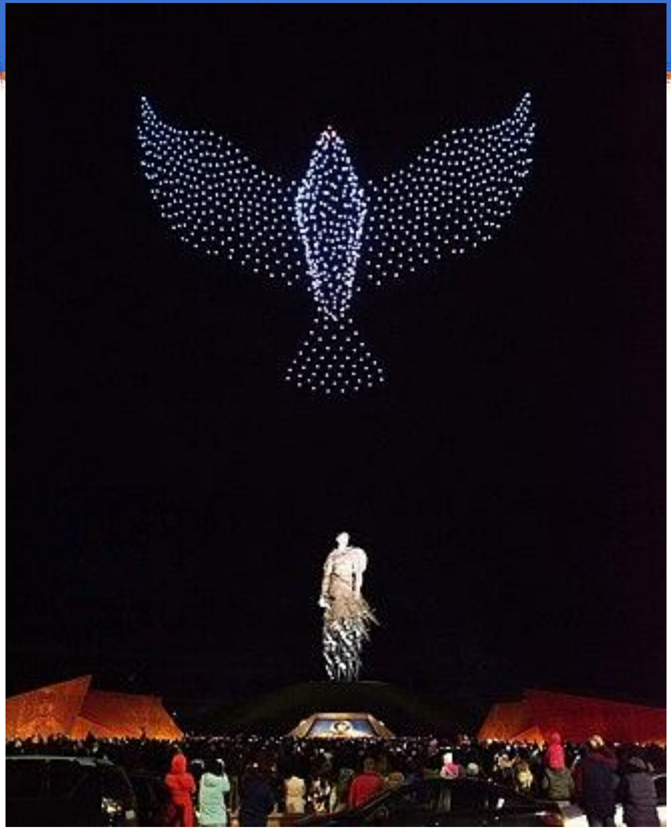

Swarm Drones
(Image Credit:Geoscan Group, CC-BY-SA 4.0)

Source: https://github.com/vmayoral/ros-robotics-companies

Robot Operating System 2

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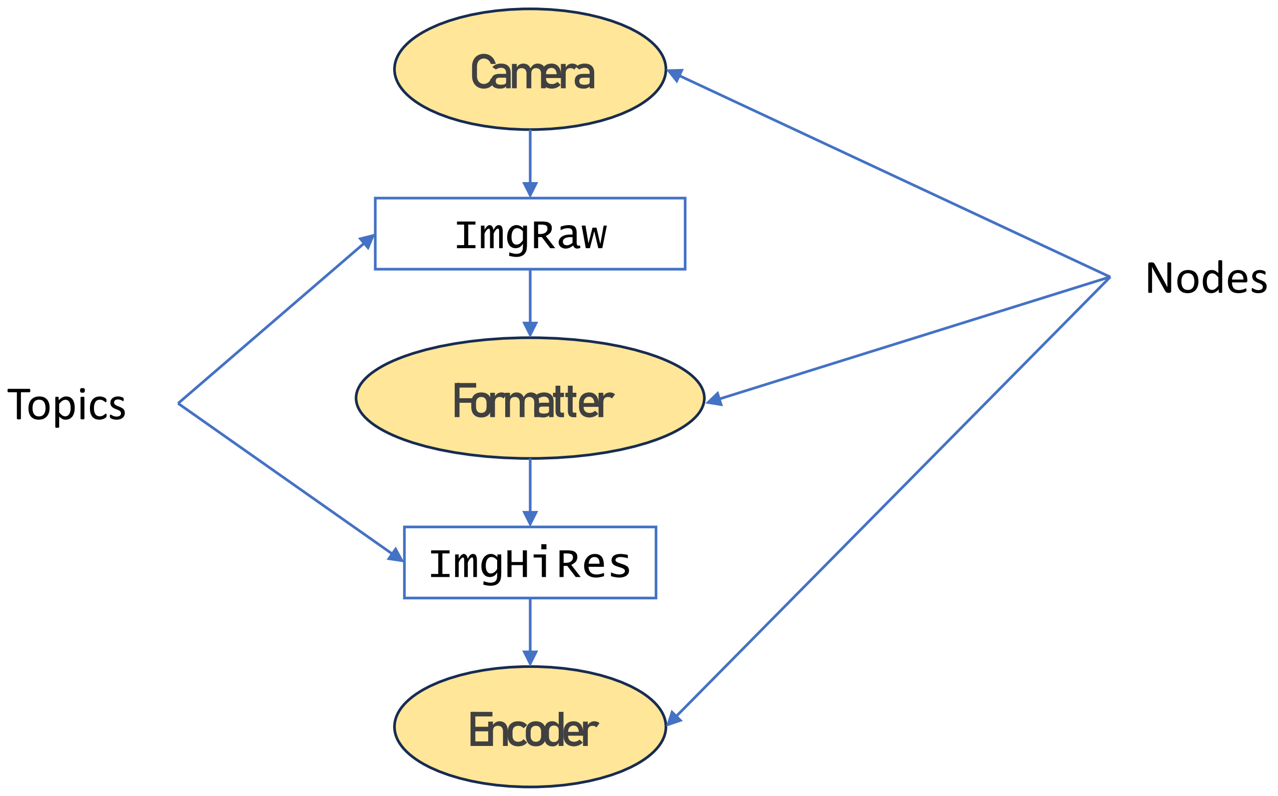

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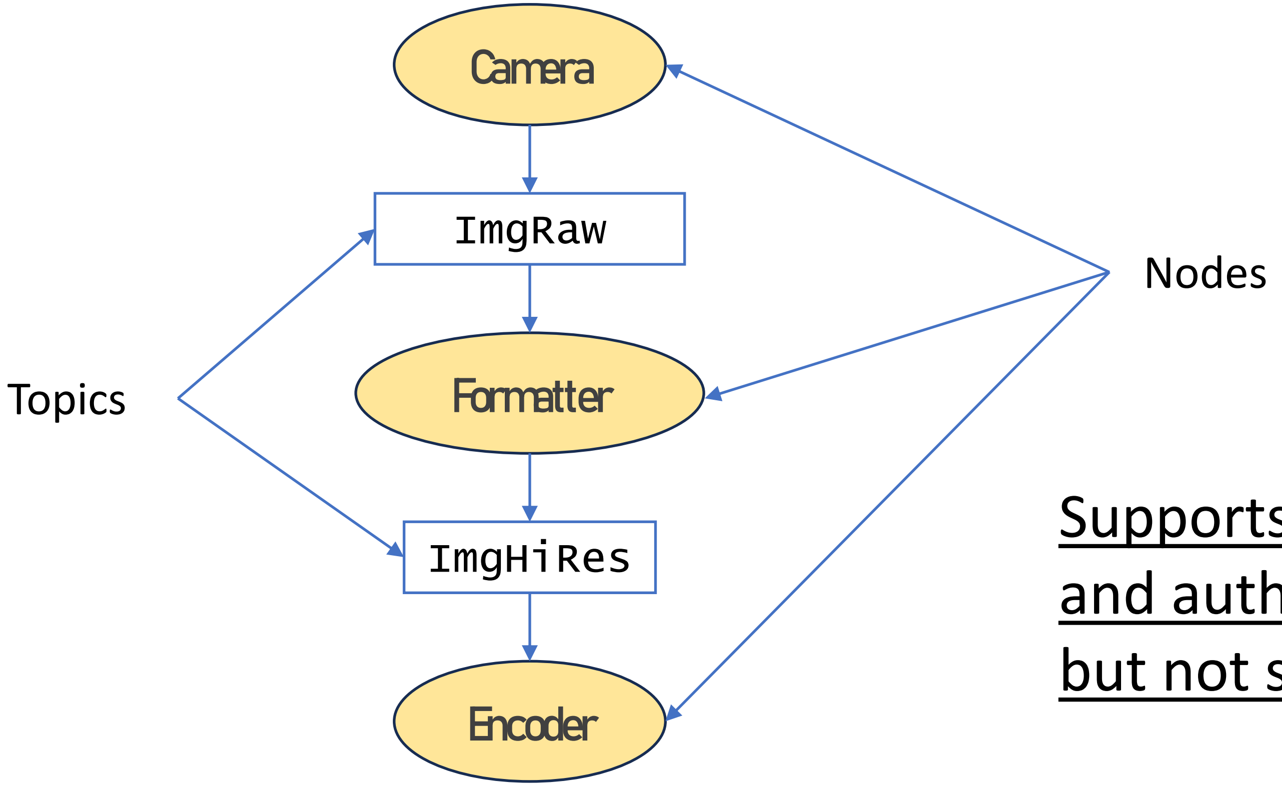

<u>Supports encryption and authentication, but not sufficient</u>

Problem of Downstream Control

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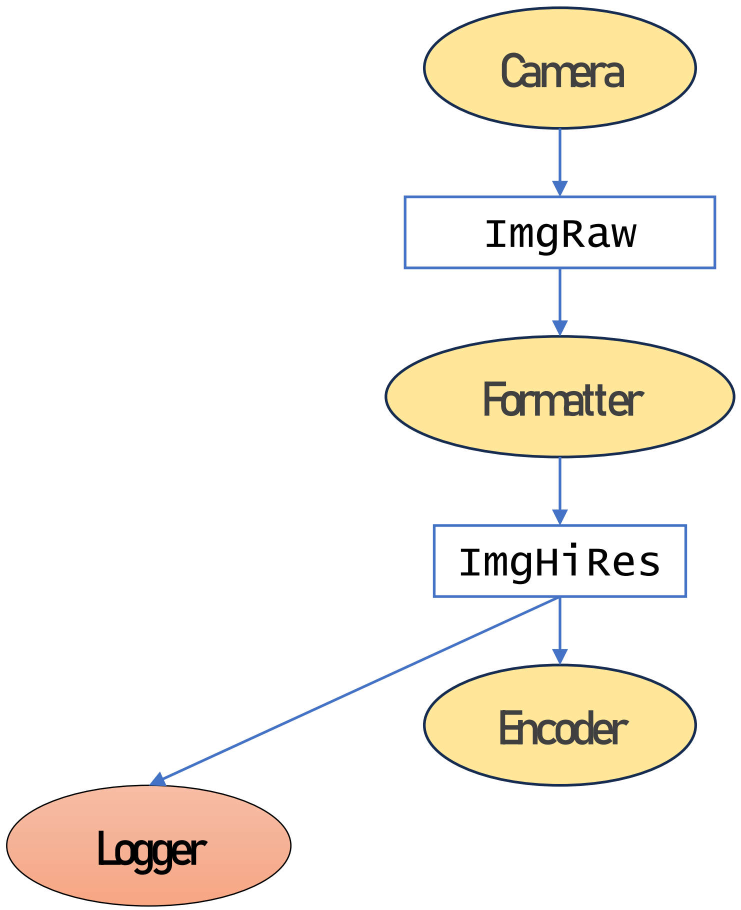

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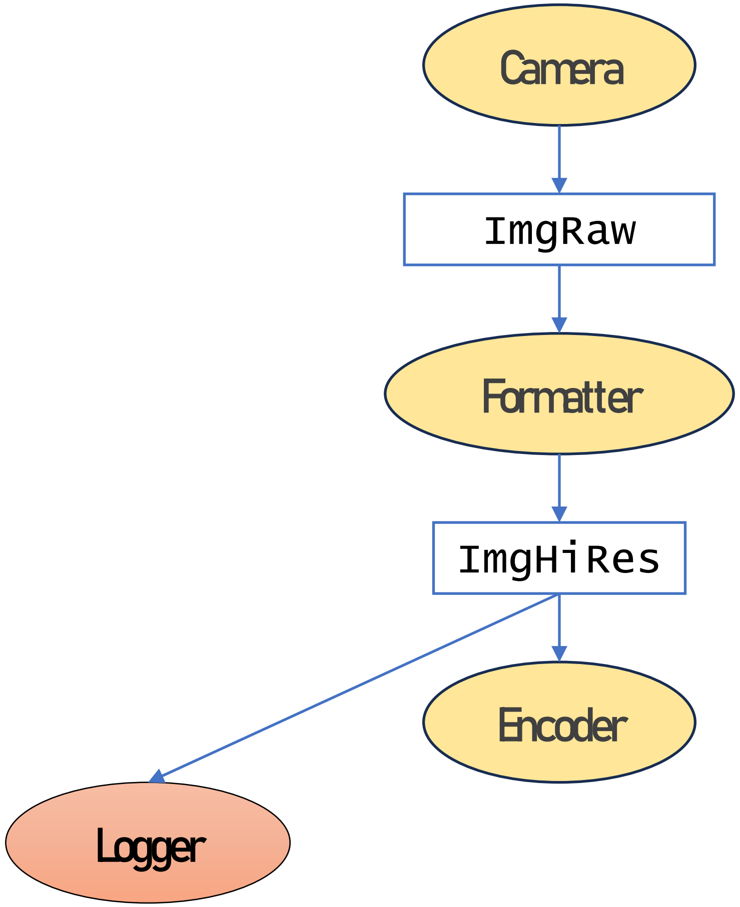

Camera can’t control what happens to its data beyond Formatter!

Decentralized Information Flow Control Systems

Decentralized Information Flow Control Systems

- A DIFC System[1] tracks path of data using sets of tags attached to messages and nodes

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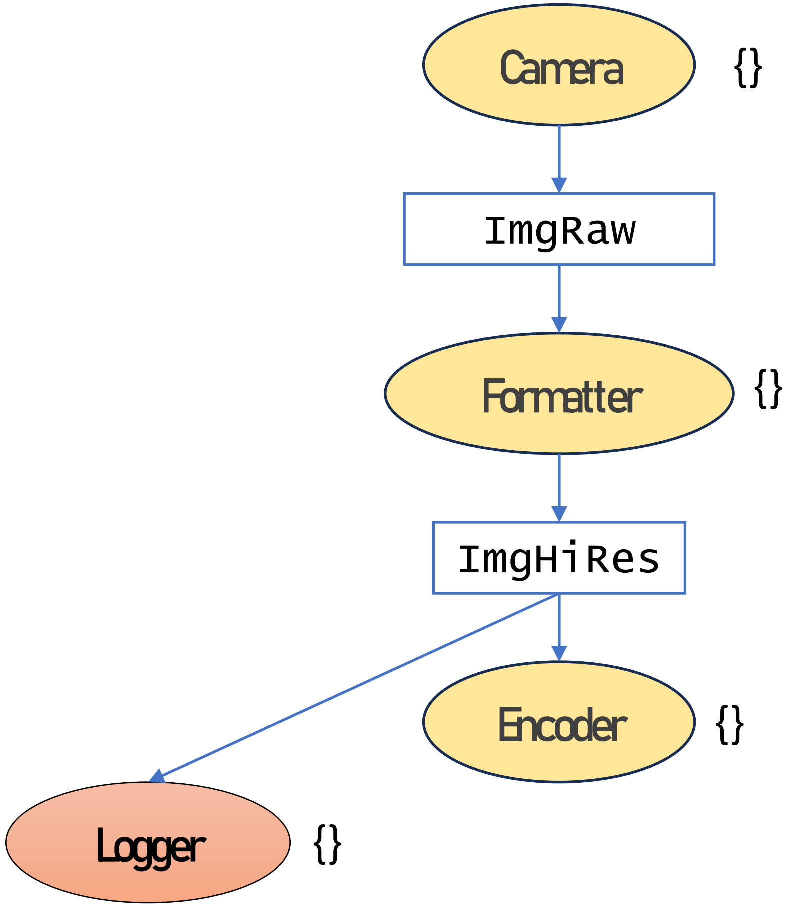

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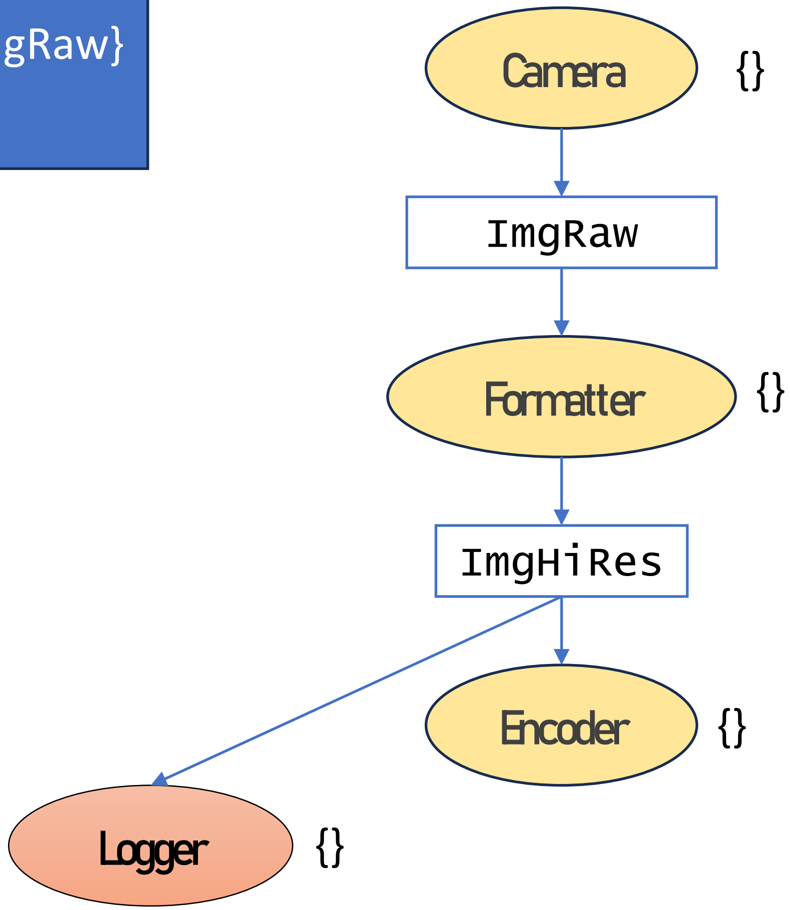

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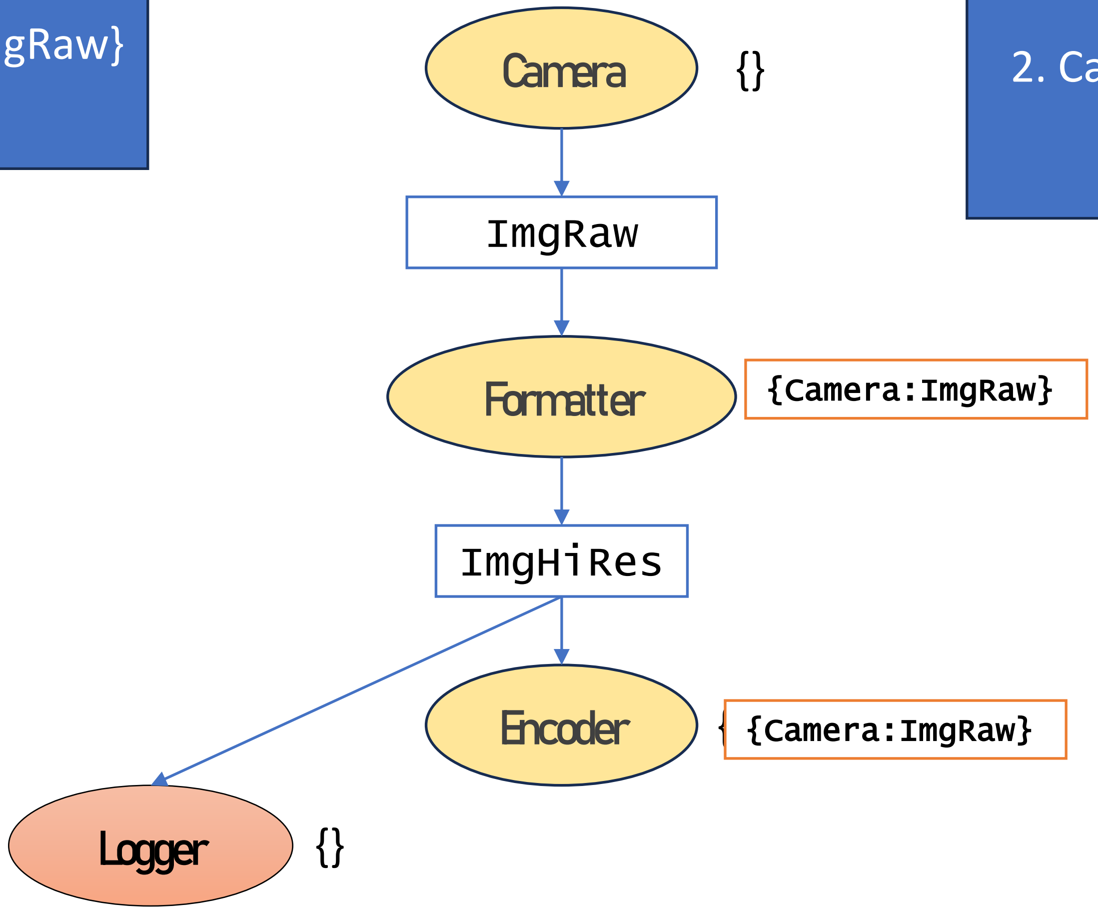

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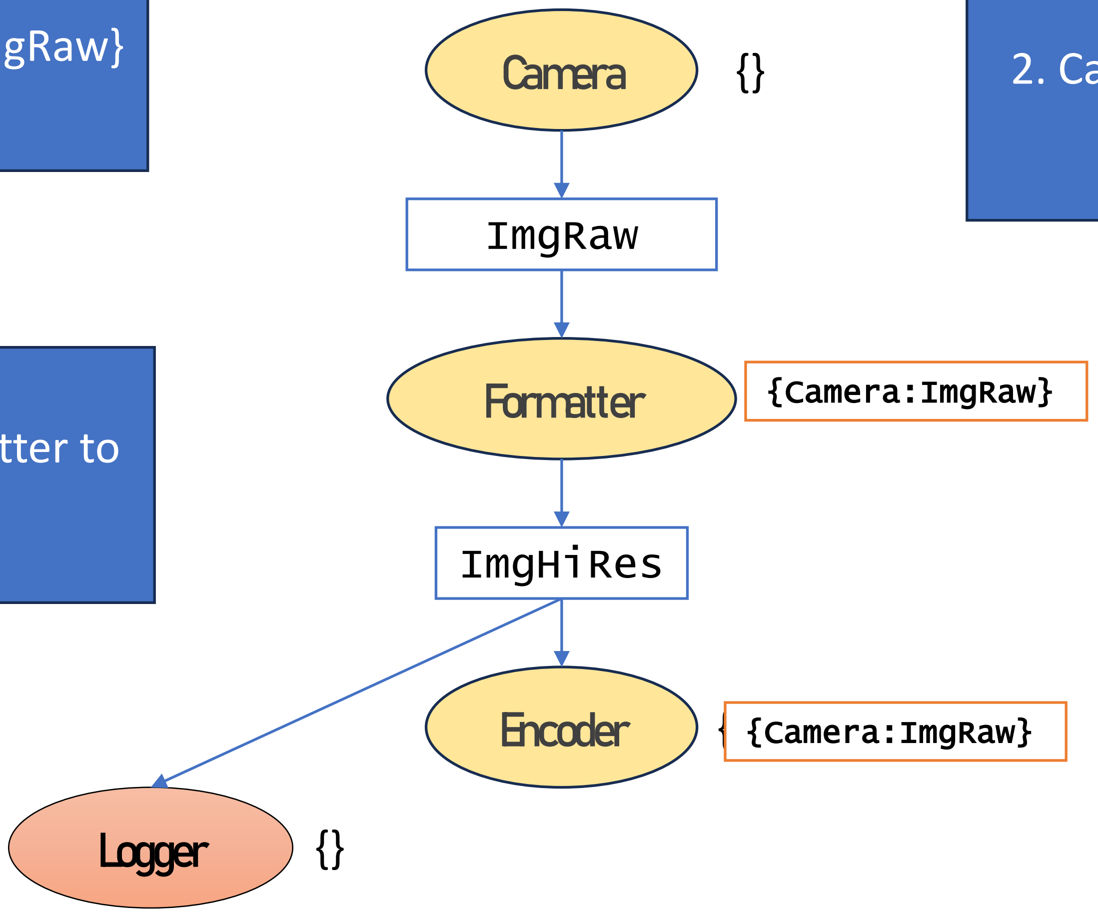

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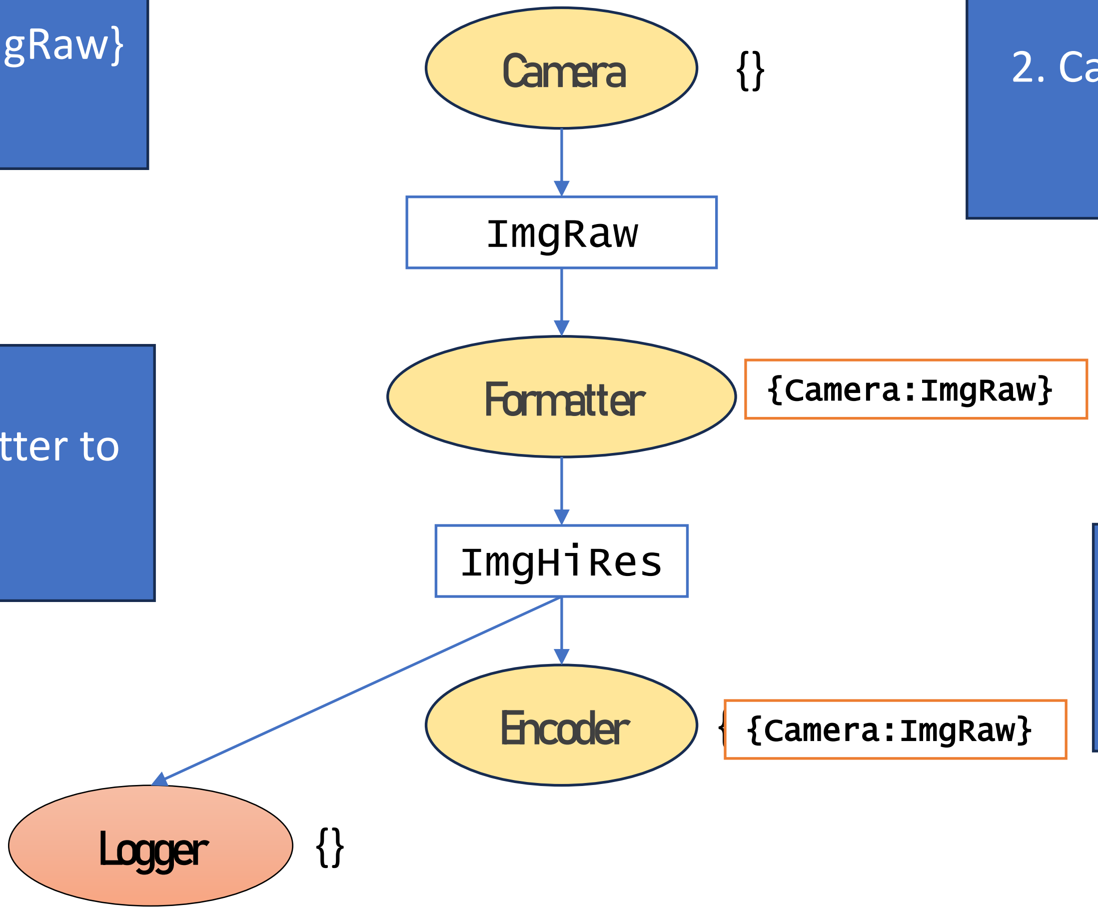

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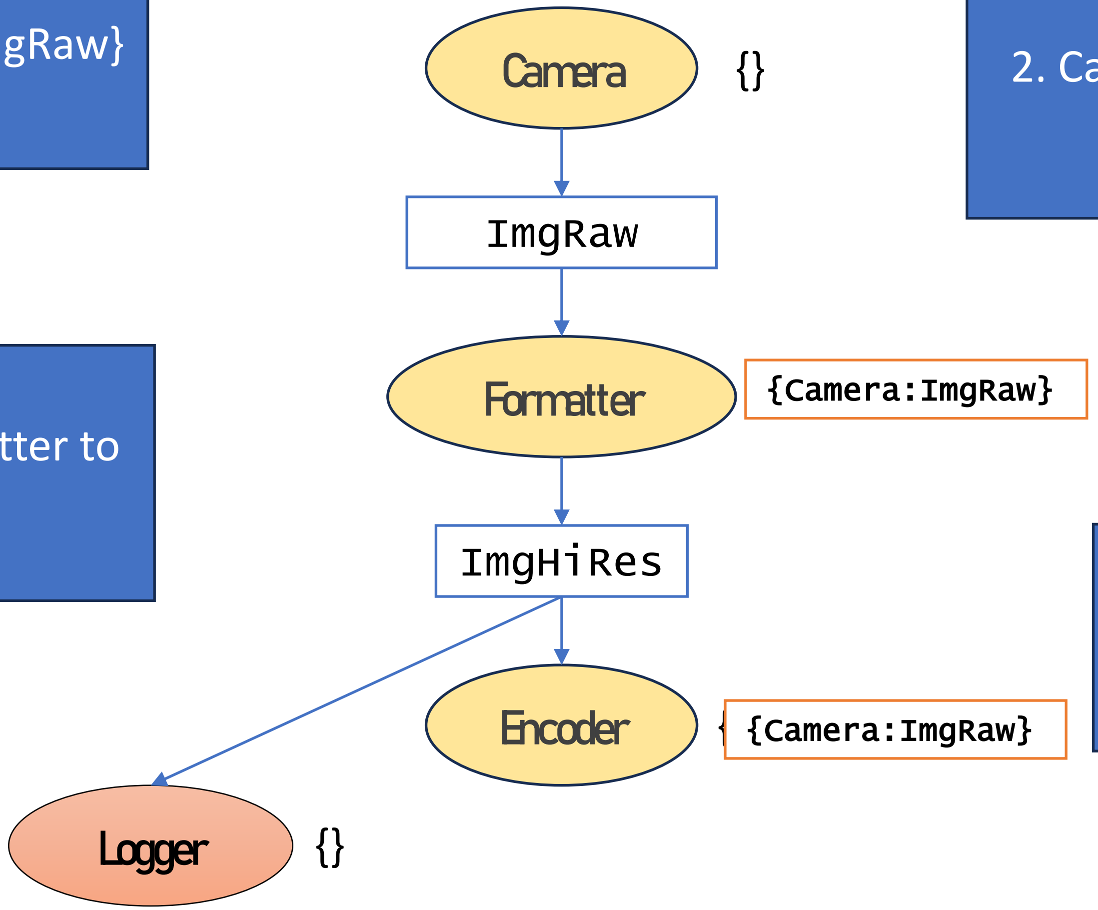

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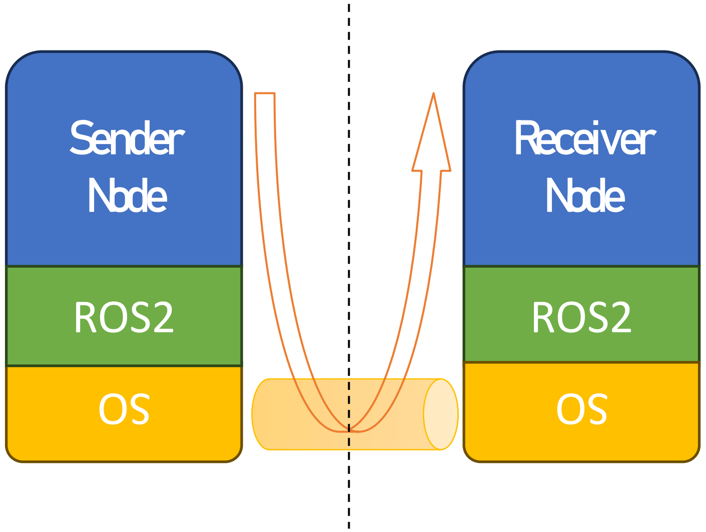
Challenges to enforcing DIFC



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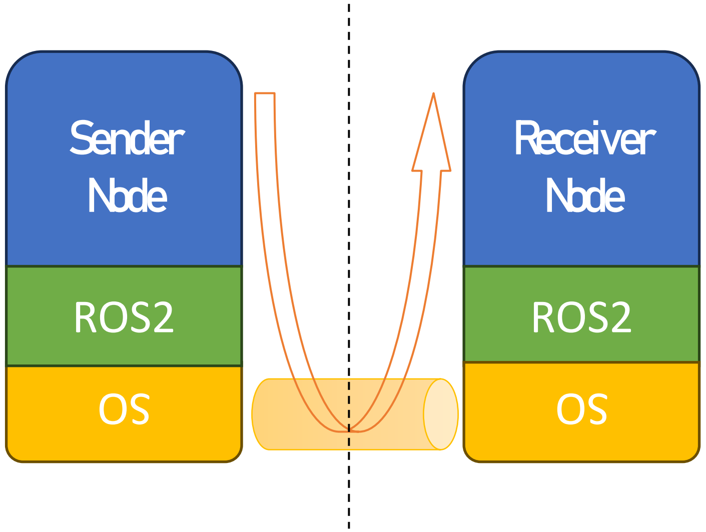

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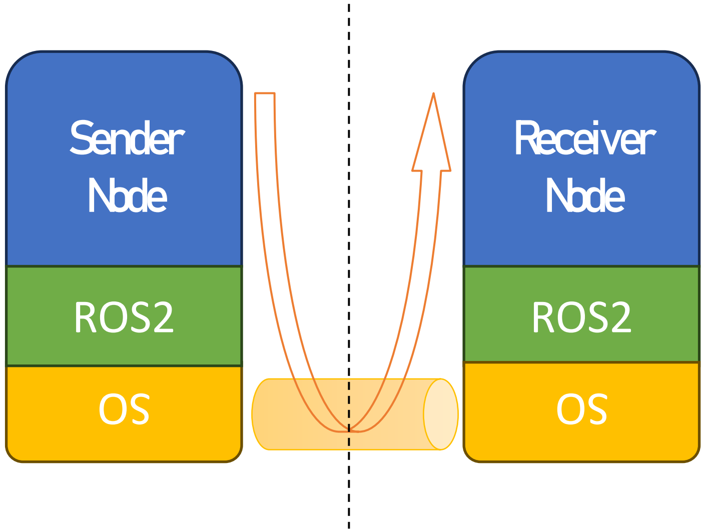

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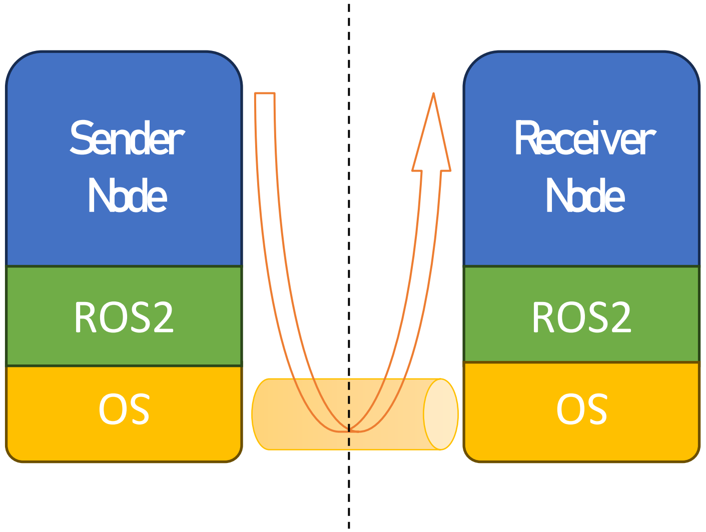

- ROS2 is *distributed* and *decentralized*
- Receiver side filtering in ROS2 too late!
- Sender side filtering in ROS2 requires trusted, centralized, state management

Our Key Insight

DIFC on top of a decentralized ABE cryptosystem[1] addresses these challenges

[1] Lewko, A., Waters, B. (2011). Decentralizing Attribute-Based Encryption. In: Paterson, K.G. (eds) Advances in Cryptology – EUROCRYPT 2011. EUROCRYPT 2011

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- Encrypt with both the public keys corresponding to the attributes
- Only those who are both “Doctor” and “On Duty” can decrypt

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- “Add DIFC tags” => Encrypting with more *attributes*

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- “Giving read access” => Handing out *decryption keys*

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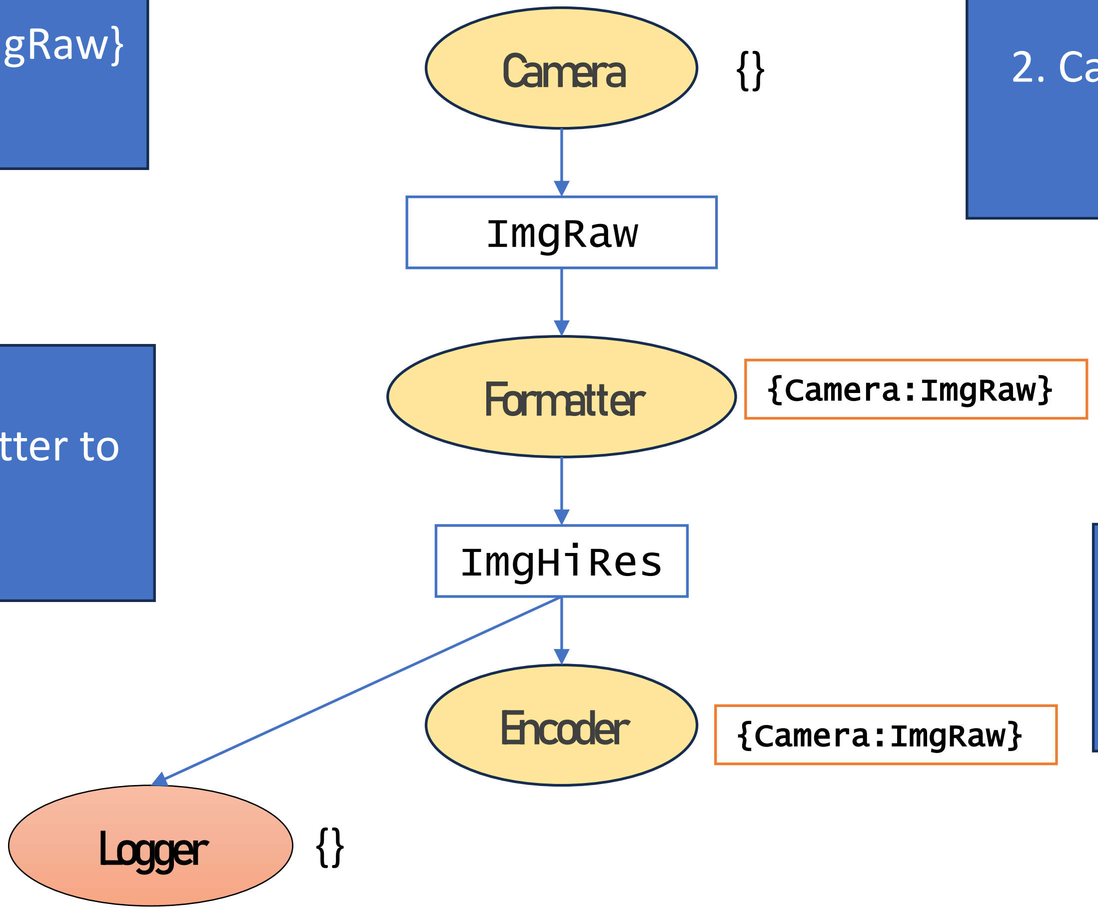

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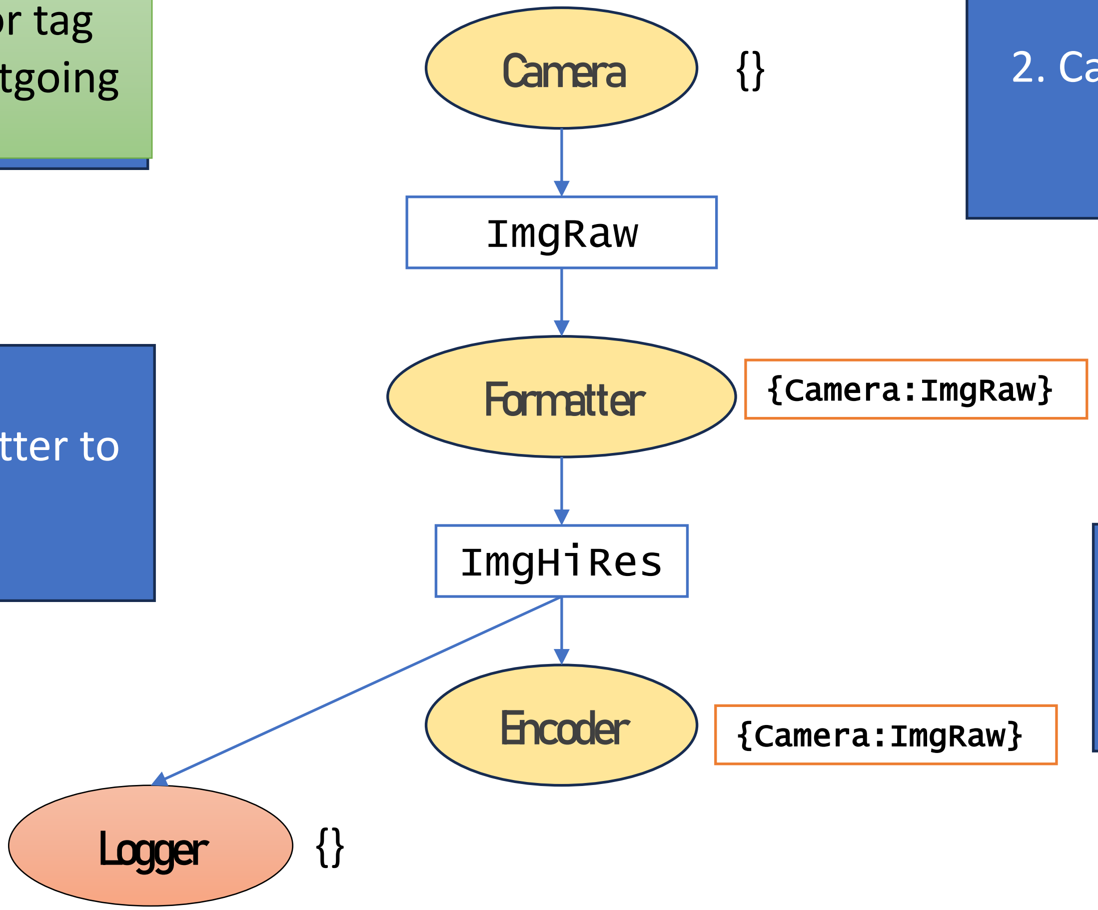

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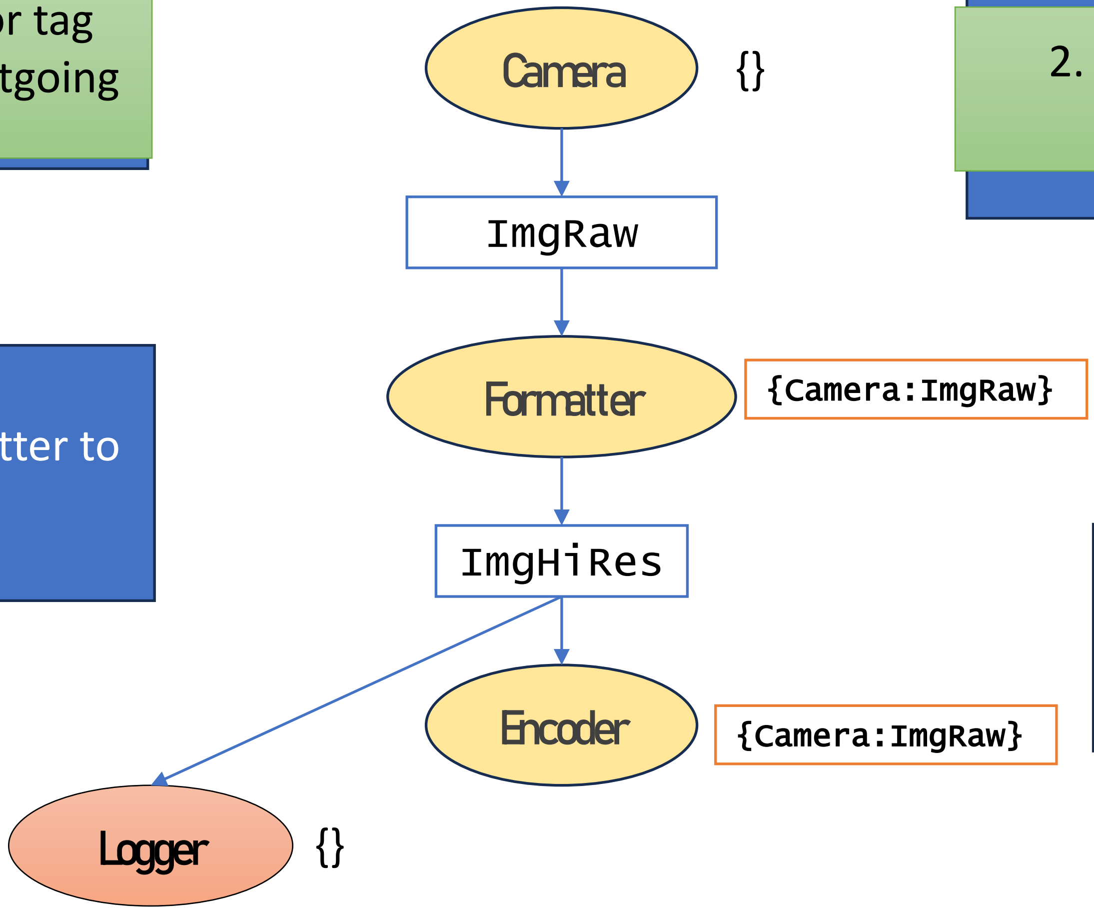

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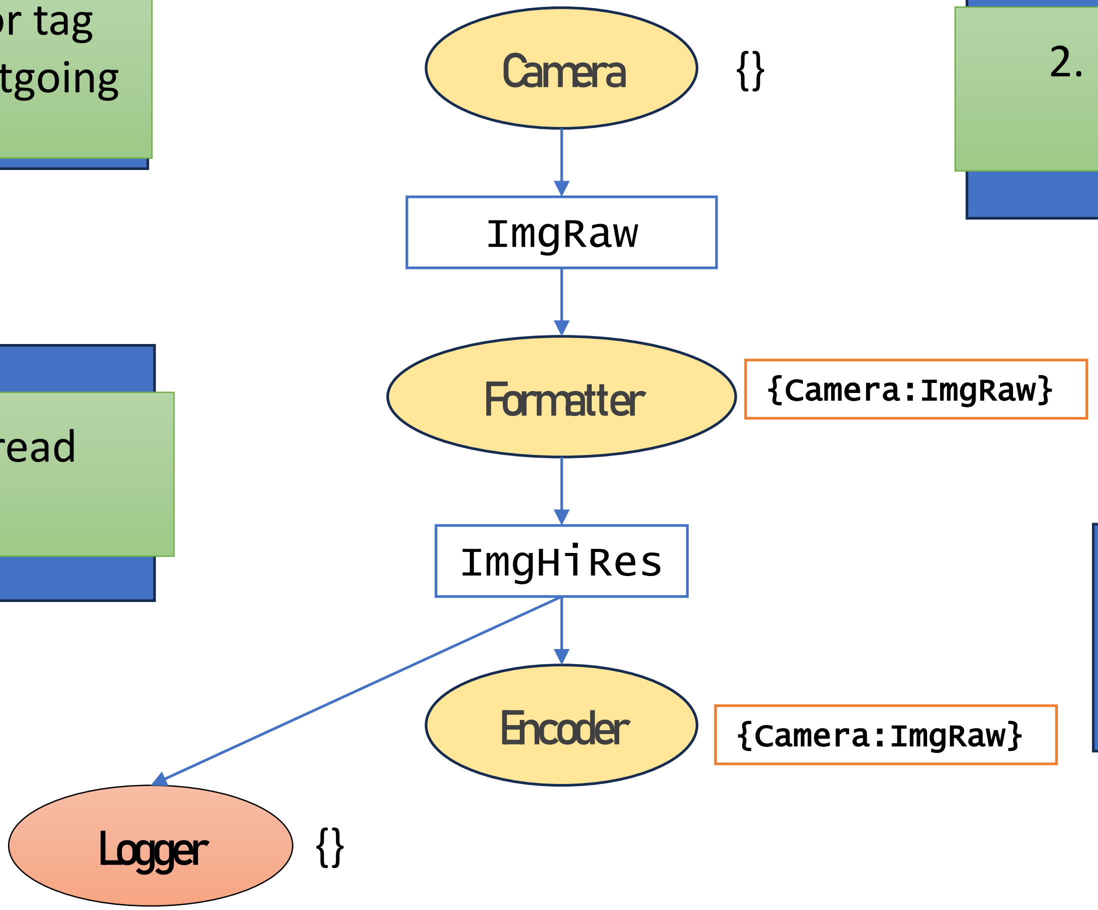

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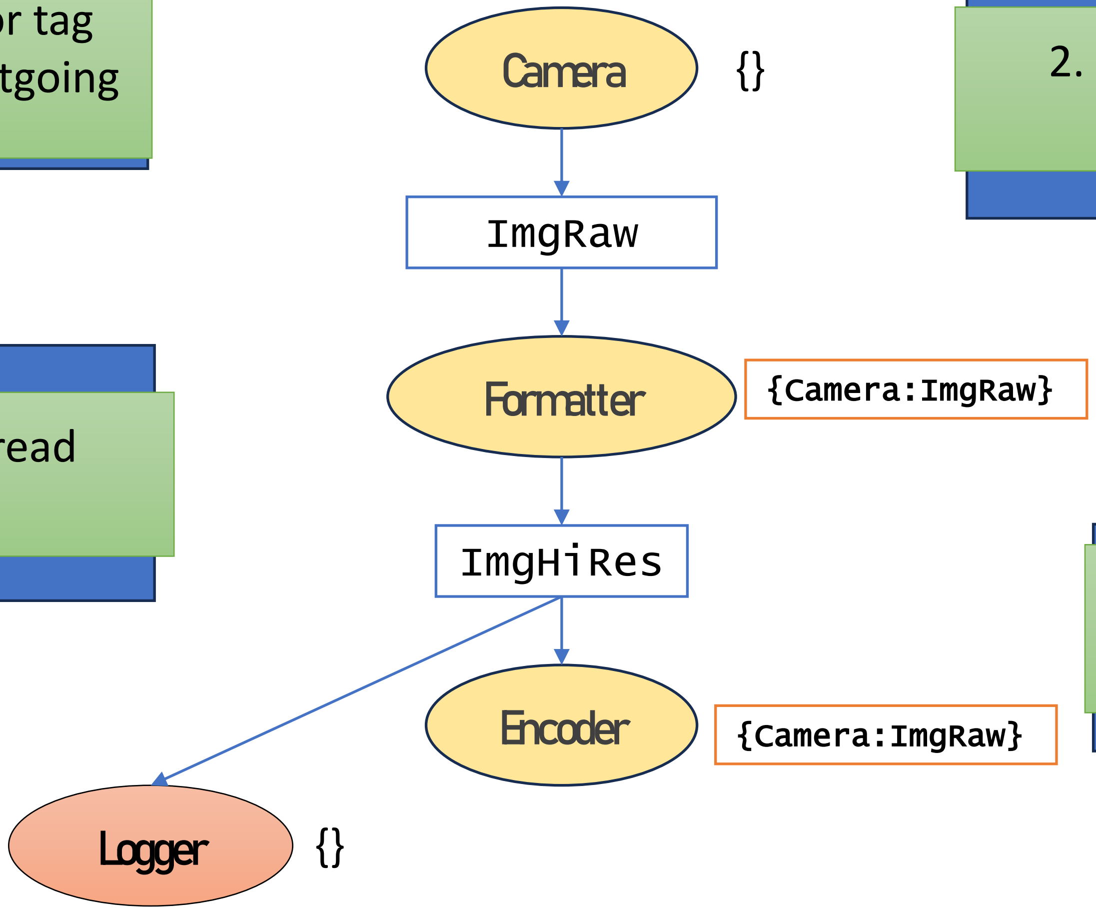

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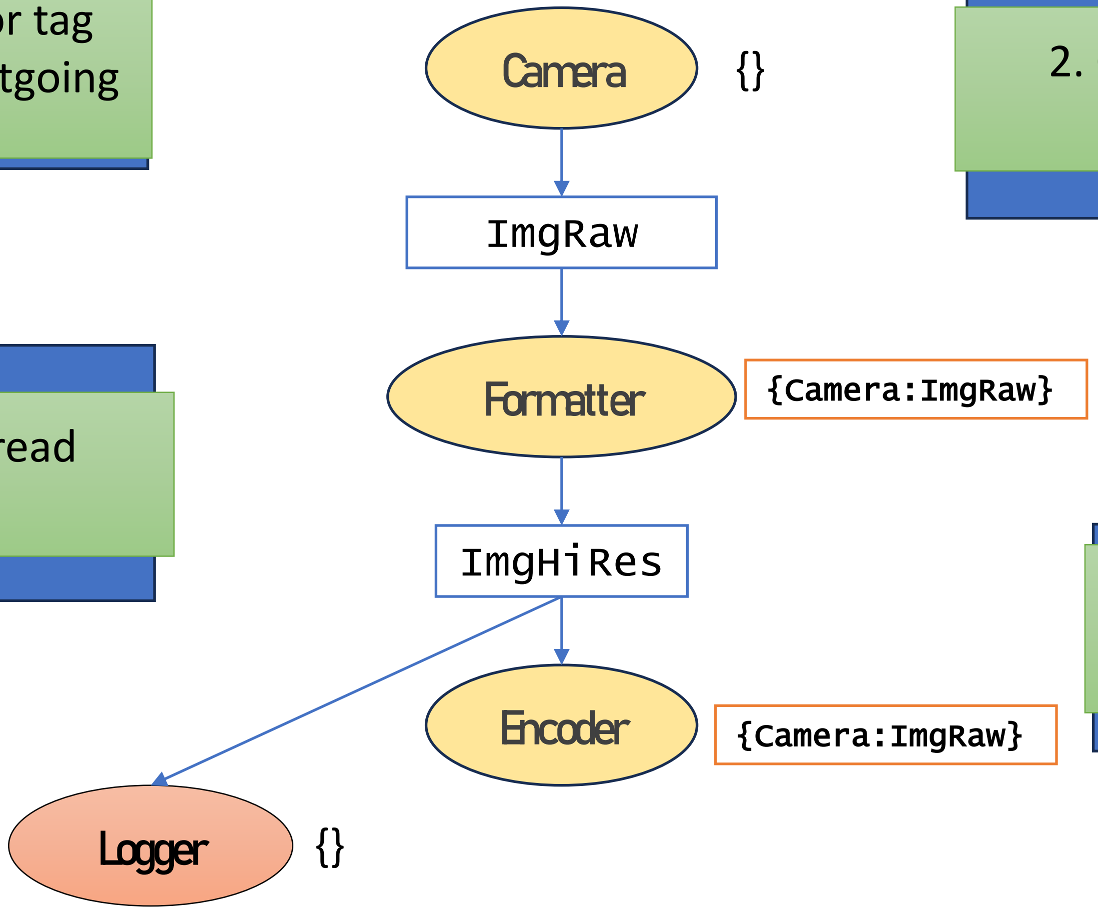

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DIFC using ABE

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- Combine with existing ROS2 security primitives
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Allows for decentralized enforcement of DIFC
Works in a distributed setting
No expensive setup phase requiring global coordination
Allows incremental deployment

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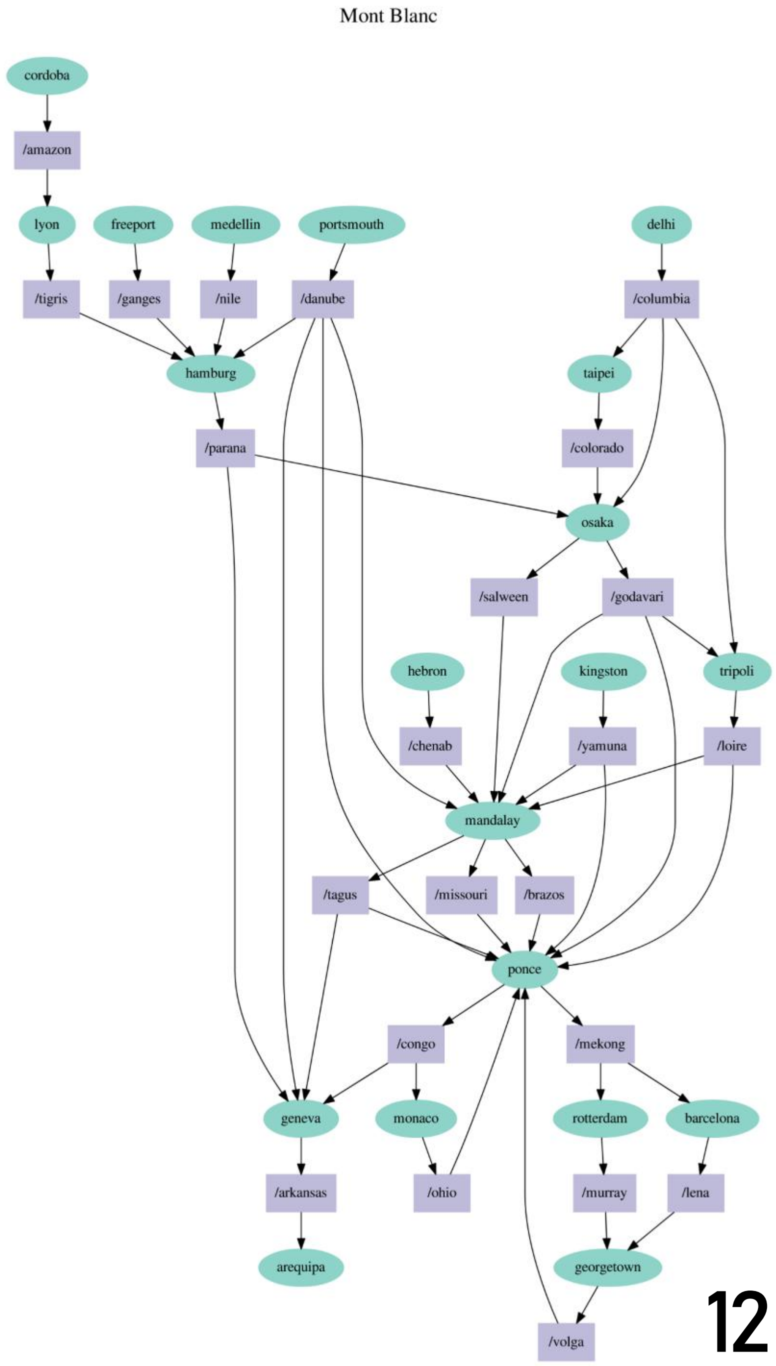
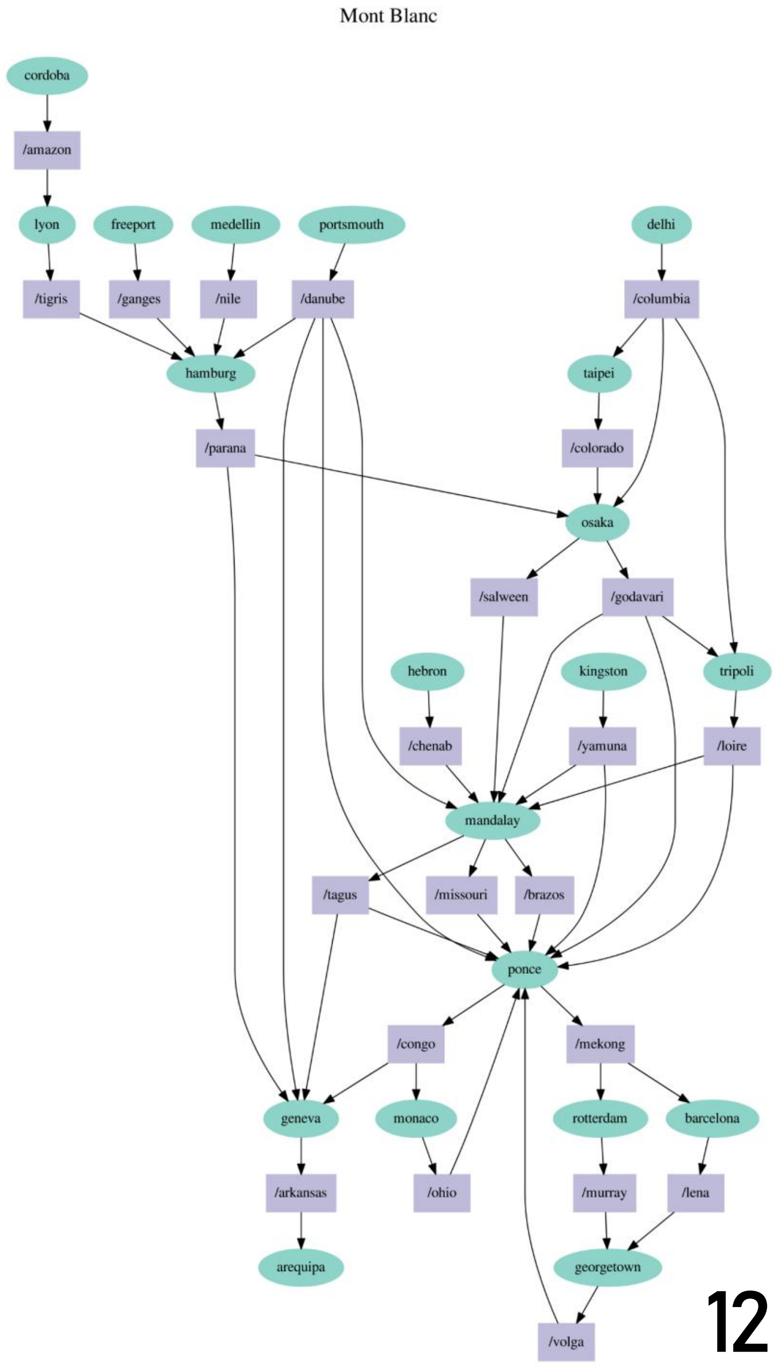


Performance – iRobot benchmarks

Topology	Path Length	SROS2 (ms)	Picaros (ms)
Cedar	3	0.85	10.4
Sierra Nevada	3	0.94	13.6
Mont Blanc - 1	5	1.34	61.3
Mont Blanc - 4	5	1.34	115.0
Mont Blanc - 7	5	1.34	316.9



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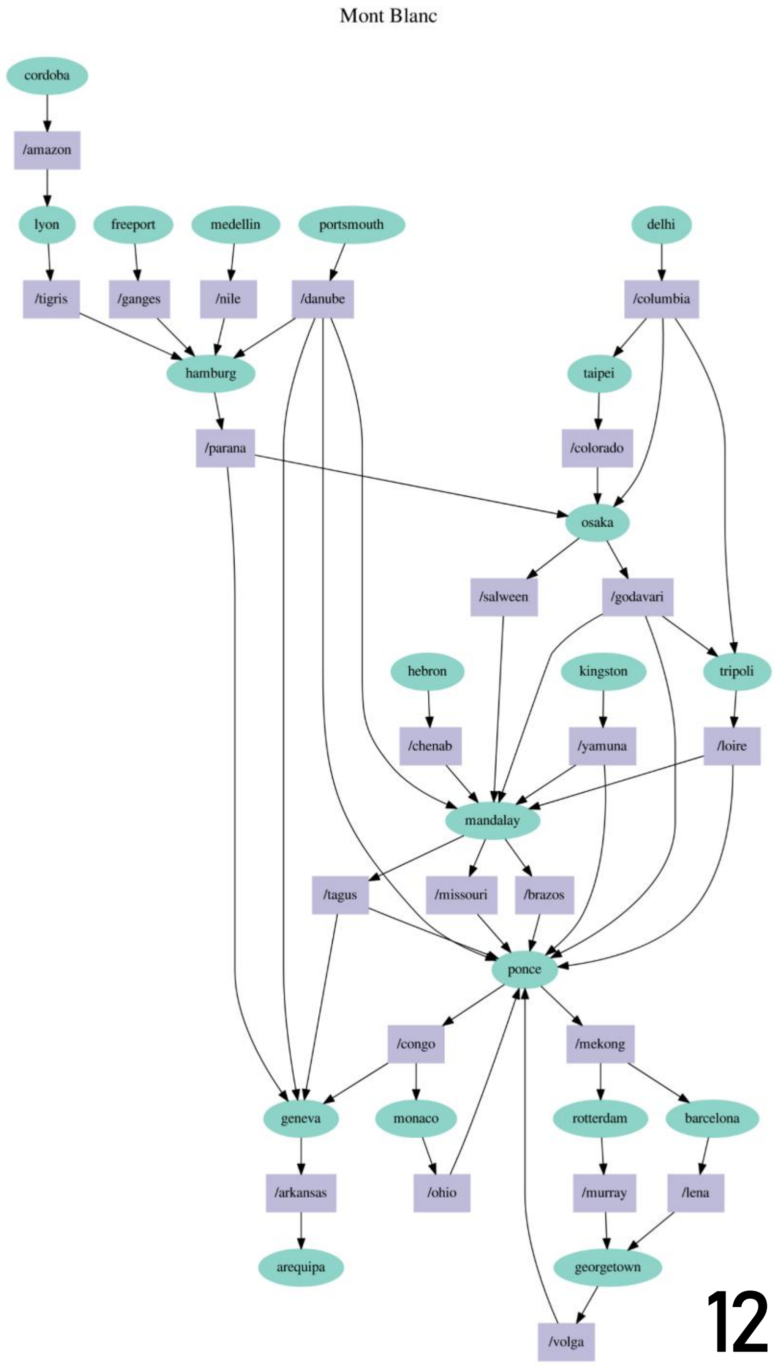
Topology	Memory Usage (MB)		Power Draw (mW)	
	SROS2	Picaros	SROS2	Picaros
Cedar	1690.1	2525.1	4896.7	5437.0
Sierra Nevada	2163.1	2442.5	4881.0	5393.0
Mont Blanc - 1	2529.3	4019.6	5056.1	5281.8
Mont Blanc - 4	2529.3	4068.2	5056.1	5295.7
Mont Blanc - 7	2529.3	4096.8	5056.1	5307.7



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- Since every node decrypts, computes, then encrypts again, latency grows significantly for longer paths.
- More implementational optimizations might help.

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- We address the problem of downstream control for ROS2 applications.
- We cast the problem of DIFC into the framework of Decentralized ABE
- ABE based design allows for decentralized, distributed, dynamic enforcement which fits in line with ROS2 philosophy.

ROS2 implementational challenges

- The OS is unaware of ROS2 abstractions
- All messages between two nodes, irrespective of publisher and topic get sent via same port
- Thus, fine grained labelling not directly possible in the OS.

The ABE API

- `AuthSetup(Attribute) → (PrivKey, PubKey):` Every user wanting to add a DIFC tag to a message generates a public, private key pair and releases the public key
- `Encrypt(Message, {PubKey}) → Ciphertext:` Encryption of a message happens with respect to all the tags the message has to carry.
- `KeyGen(UserID, Attribute, PrivKey) → DecKey:` User Specific decryption keys for every attribute
- `Decrypt({DecKey}, Ciphertext) → Message:` Decryption requires decryption keys corresponding to all the tags the message carries.