rmw zenon

An alternative open-source middleware for ROS 2

Phani Gangula

Senior Solutions Architect phani@zettascale.tech





Background





Zenoh: The RMW Alternate

Zenoh has been selected as the first non-DDS protocol to be natively supported in ROS2

Intrinsic is already implementing Zenoh RMW as the major contribution for next ROS2 release

The full report is available here

2023-09 ROS 2 RMW alternate

Abstract
User Challenges with DDS
DDS has a fully-connected graph of participants
DDS uses UDP multicast for discovery
DDS can have difficulty transferring large data
DDS can struggle on some WiFi networks
DDS tends to have complex tuning parameters
Vendor specific non-standard DDS extensions
Next Steps
Requirements gathering
User Survey
Demographics
Technical Data
Alternative middleware options
Requirements
Comparative analysis of currently available middleware
Complete list of investigated middlewares
Performance
Middlewares X Requirements
Conclusion
Appendix A
, hkanan , muunin , m

Conclusion

Requirements from ROS 2 users were gathered, and middleware options that are available today were investigated. The research has concluded that Zenoh best meets the requirements, and will be chosen as an alternative middleware. Zenoh was also the most-recommended alternative by users. It can be viewed as a modern version of the TCPROS implementation. and meets most of the ROS 2 requirements. There are still a number of design decisions to be made regarding this implementation; those details will be discussed on https://discourse.ros.org as development begins

 1
 2
 2
 3
 5
 6
 6
 8
 9
 15



Best Fit

Zenoh stands-out as the protocol that satisfies essentially all requirements identified by the survey



												the second
- Personner		in the second	205		-	174	Modemary C		OPC-UA	TOPROS		
- Pute	Level	CORTA	101	64	Eatha	LON	HOLD .	8000	TALL MARTIN A DOUBLE PARTY	autrus .	(Reall	- A - A - A - A - A - A - A - A - A - A
Louis-	-		101		The lot is not set of the lot of		16.53	10,31	-	11.003	10,715	alandar Data The Short's party and
inter .	144		-		-	-	ter.	-	-	19.54.5		Not an over presided, that have well it have not an out of president of
Bellevilla Marriel	and a	-			2				-	201 (1967)		And their counties to generate their law
Coast			Anderine in 127 with called our in Stream I				38	-			BLOOCH JR. DLOS	
Concernation Intendie addiscontractions.com- ent of the estimate	-	-	Personal and a second s	Territolice a LEOF audio the obtack, protect of its property in TEP mode, and the balance for the or restrict stream	The Allowing Address and Com-	-	54	-	-	-	-	-
Senarch cargo.	No.	(income	Animite when for outsides, on image is undised for the parallel.	And Median, in 1929" wants the cardinal powershi with the integrate, in 1929 mode, if will handle their better, but the to said the statest	An Apple 1 will get the	The local de l'ese-contract	Terling to be if while TOP (FBD)		Nation are also SCP also	Vesting or instal and TOP allows	-	
Configure which address in the control of the contr	No.	and and	16.1	The lots marited Lines (arrigerative)	95	195	the supervision of the supervisi	to be as Air to estimate advise	10	indexide through the studies splice	We achieve a call	Por Selft Nal Instruction that SHIES
Apply-to-used multi-image/um recoupy-	-	-	Brotherines to USP received, parameter derived of heterometer and none. Belanci configuring another hetero anno onto constants in trans and packets annue who may and their later to researce of sciences.	No. kel olit osnati etnat oliga os olici transpot tojat Biti alli Olitik No. Olitik No. NO. No.	-	-	Andrew St. 18th Description	-	*	-	-	Bastin ins 12 ar
Although the	-	Par Sale Sale Sergeon Ingenet	**	Britelin satisfait with the SM temport likeling to bootstate the patterner's units their fair to anisother, and od to be:	The Apparently interest of Just in Advances	-	-	*	Main 18	- 10	m.mourrantes	-
 Scoul Assess attack to caching attacks 	-	Charlot All Charlot and controls controls	-	In 189 Indexe descerpt	-	-	-	-	84.	- 14	Vez Discourse bagance shall a securit resident to constant a regil again start in both for share performance.	-
- Transporters	**	inter.	burnerster ge fi	Line, Bining res(0)	Max, Just 1000; 1010 anywhere a 20% mers	Loss Mintee, rep.(2)	-	line Brainet real?		ATMA MINIMUM (FOR ANTI) MINIMUM (MINIMUM)	Loss, Mindows, Hand Mil	lines birthing, read/10
Con agricult	Red .	er.	beirroute auch	Assuthe 210	Assets 21	LEP.	Inclosedulariande	107.	Interview and		Aparte 12 and Libra Pattolanne 12	MPL18
- Intelligence	Second	-	in.	No. 189 edited	-	To provident LOP-scale	Addressed in control in column 2	The Observation of the second state of the sec		144	The Dath process and . 2.9 mant	Name and Address of the Address of the Address of the
- Protoganse	Det		Sector in a sector in a cost fragment with problems when relating rest well managed industry. (TE, managed COP 1982)	Onlinging to stread, some part million US ⁴ . Car on TCP to world its.	70	Colleges - cantor see it	No recommendations	*	701 of 707 albest	75.470 AM	The extended reader	We provided to have not bridged
inest compy	mut	0.00	The property sector is a service of the sector of the sect	**	No. You, or, shows when a manual to the manufacture of manufacture of the manufacture of manufacture of the manufacture of the manufacture of the manufacture of manufacture of the manufacture of	14		-		- 14	Gandoone	~
- *********	(Paul	-	-	the (diff solution	An dearty, To' produce on declaration (reder, and dec end had increased.) The right and increased. (12) (2) (2) (2) (2) (2) (2) (2) (2) (2) (-	-	-	-	1	-
 SPC Hermon debuggers 	Min	- 14	httphe	.ms (122)	- Vea	Ballader	Notada a	Number of some	- 10	Technic	No factor	XxMillionLinessite.com
- Honory (CL), CU, Honory & physics, All:	Ma	1.00	The Departmentation specifics	The Procedure and Administration	(796.)		Be Josherseller and Li		94.			Recent for two Buckformation and Machine and Contraction States
Providence of contract of the second contract	**	. 14			Real of represent of anti-devices, set the loss and	*	*	*	In any Persistence		S. Annaharan generati anna dir. Manang di X. Manan Lanan Manang di X. Manan Lanan Manang di X. Manang di X. Manang Manang di X. Manang di X. Manang Manang di X. Manang di K. Manang di X.	
- Goreensor Maaility gas	**	-		the barries and any UP with	-		-	The Same "Applications that events any set of the set of the set of the set of the events of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the set of the se	~	~	The set has be shared, or computer setter	The granitized processed or here to be
Contractorial News	Ma	1.	100 M		-	14	The Article of the		100021-00		Tel Don & a property lange of source and the source of the	
- Dentity	Max	babate	-	Anan	-	Arrists.	94	Relation feature				Castle C
And the second part	-			WALKS CONTRACTORS AND	-		-		and a second	0	100	and the second

/uV40Kjw/edit#gid=1189402529



Middleware options



//docs.google.com/spreadsheets/d/18SgD-aFJAlDus5cYMN-va9greOgXg-ErVEs

Zenoh





data centre

Built-in support for zero-copy and shared memory

Dragons teach us that if we want to climb high we have to do it against the wind.



Pub/Sub/Query protocol that Unifies data in motion, data at rest and computations from embedded microcontrollers up the

Provides location-transparent abstractions for high performance pub/ sub and distributed queries across heterogeneous systems

Runs Everywhere

Written in Rust for security, safety and performance

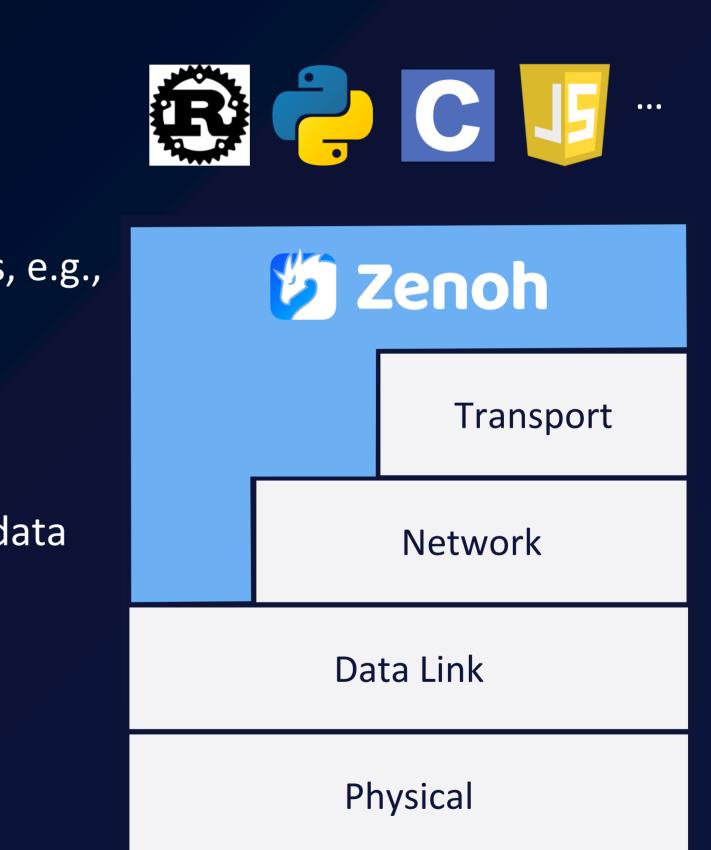
Native libraries and API bindings for many programming languages, e.g., Rust, C/C++, Python, JS, REST, C# and Kotlin

Built-in support Shared Memory and Zero Copy

Supports network technologies from transport layer down-to the data link. Currently runs on, TCP/IP, UDP/IP, QUIC, Serial, Bluetooth, OpenThreadX, Unix Sockets.

Available on embedded and extremely constrained devices and networks — 5 bytes minimal overhead





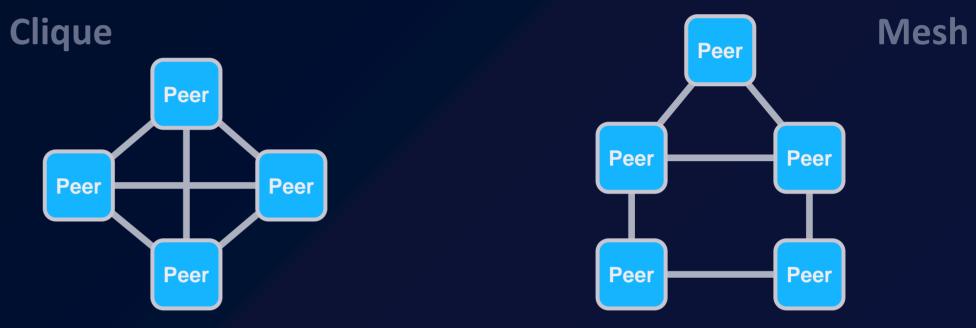
Any Topology

Peer-to-peer

Clique and mesh topologies





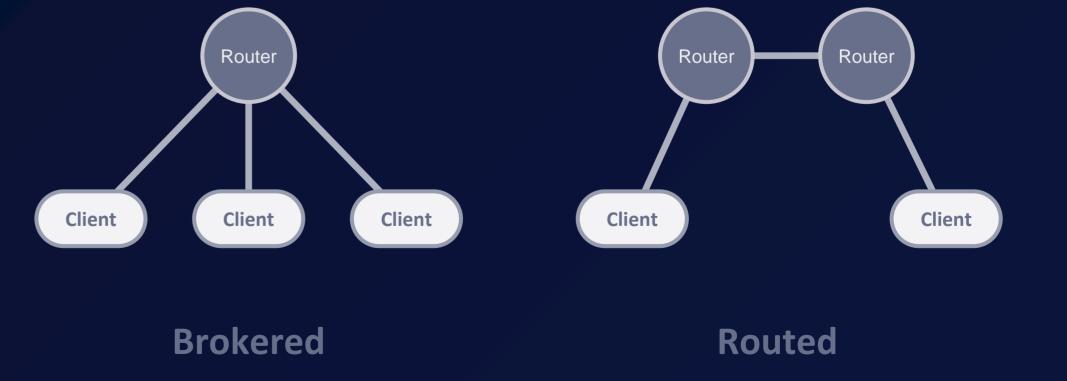


Any Topology

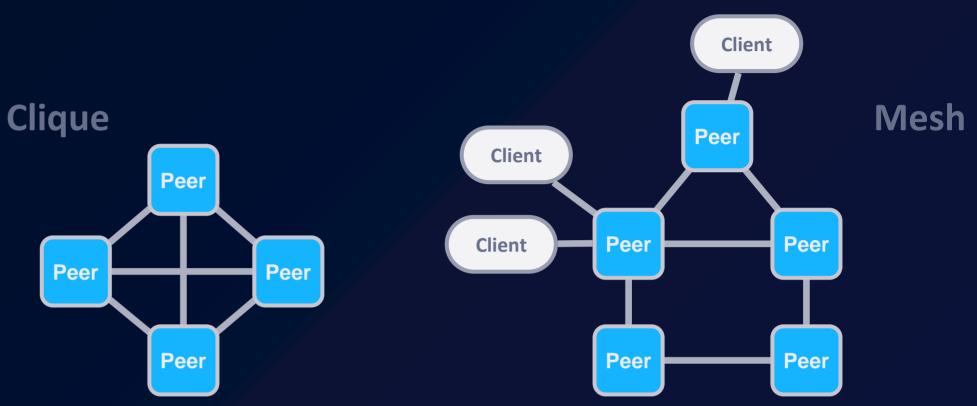
Peer-to-peer Clique and mesh topologies Brokered

Clients communicate through a router or a peer









Any Topology

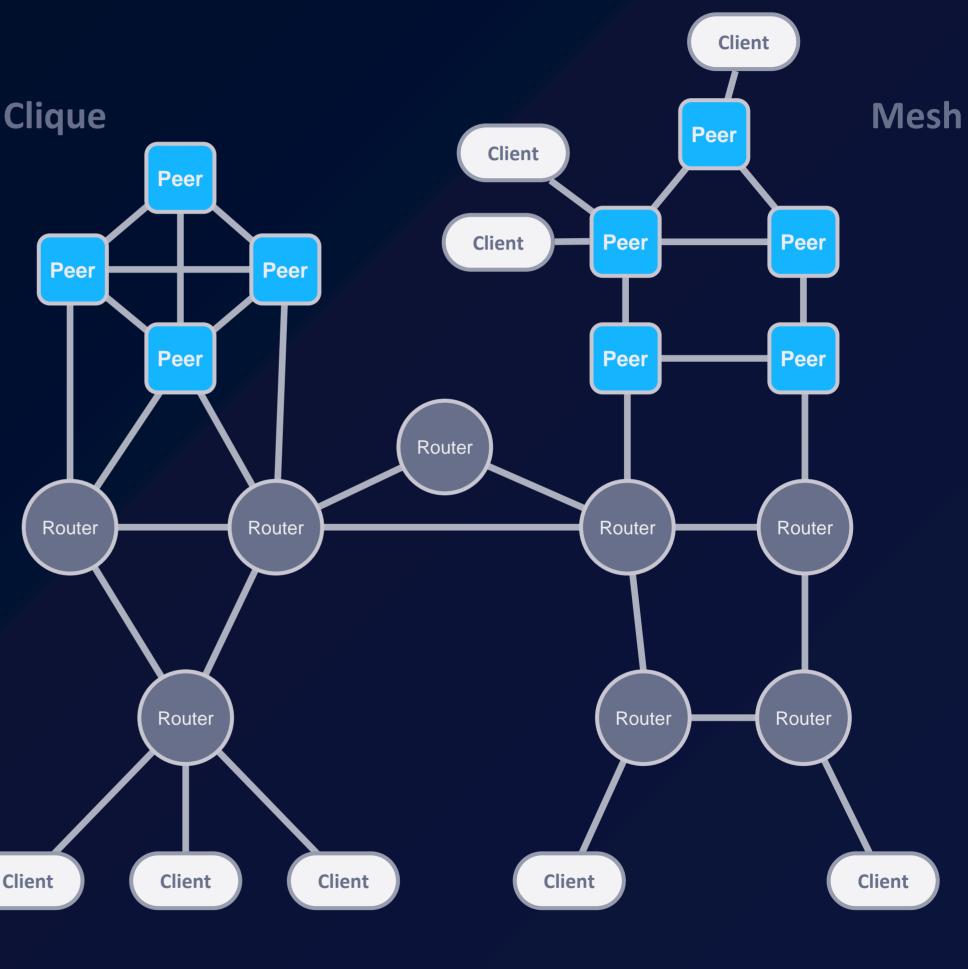
Peer-to-peer Clique and mesh topologies

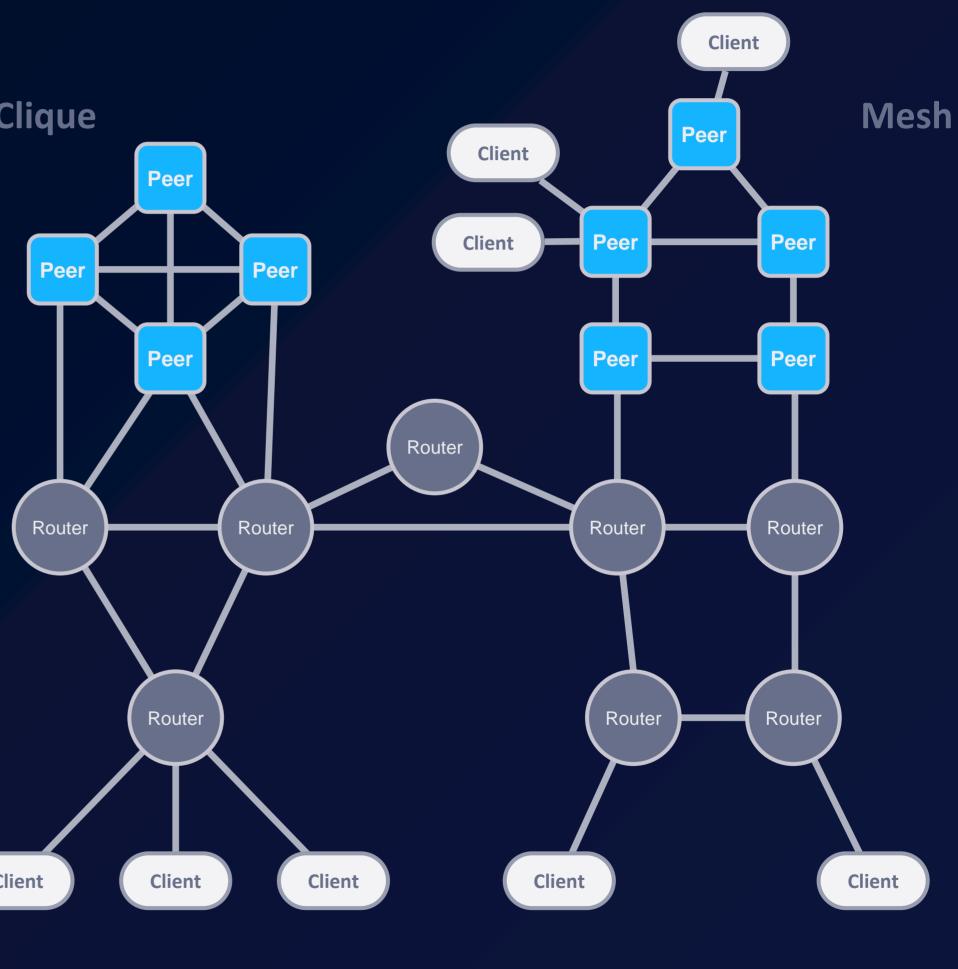
Brokered

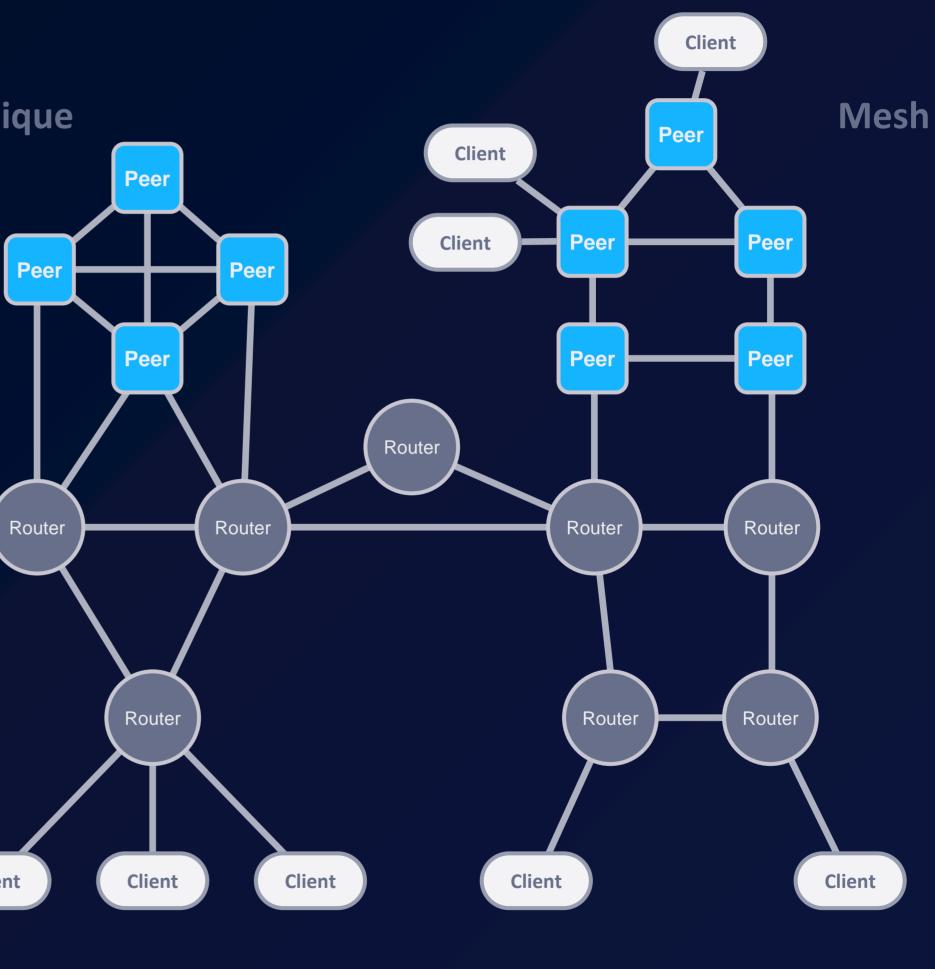
Clients communicate through a router or a peer

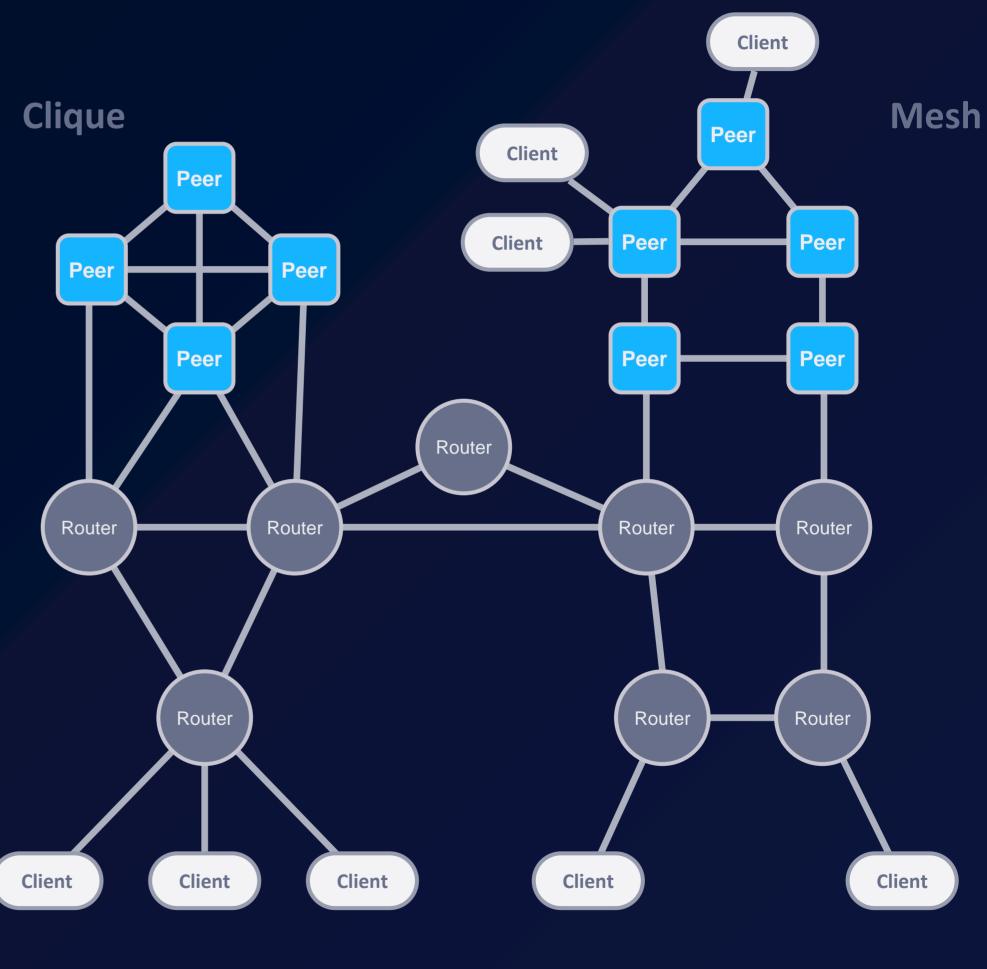
Routed

Routers forward data to and from peers and clients







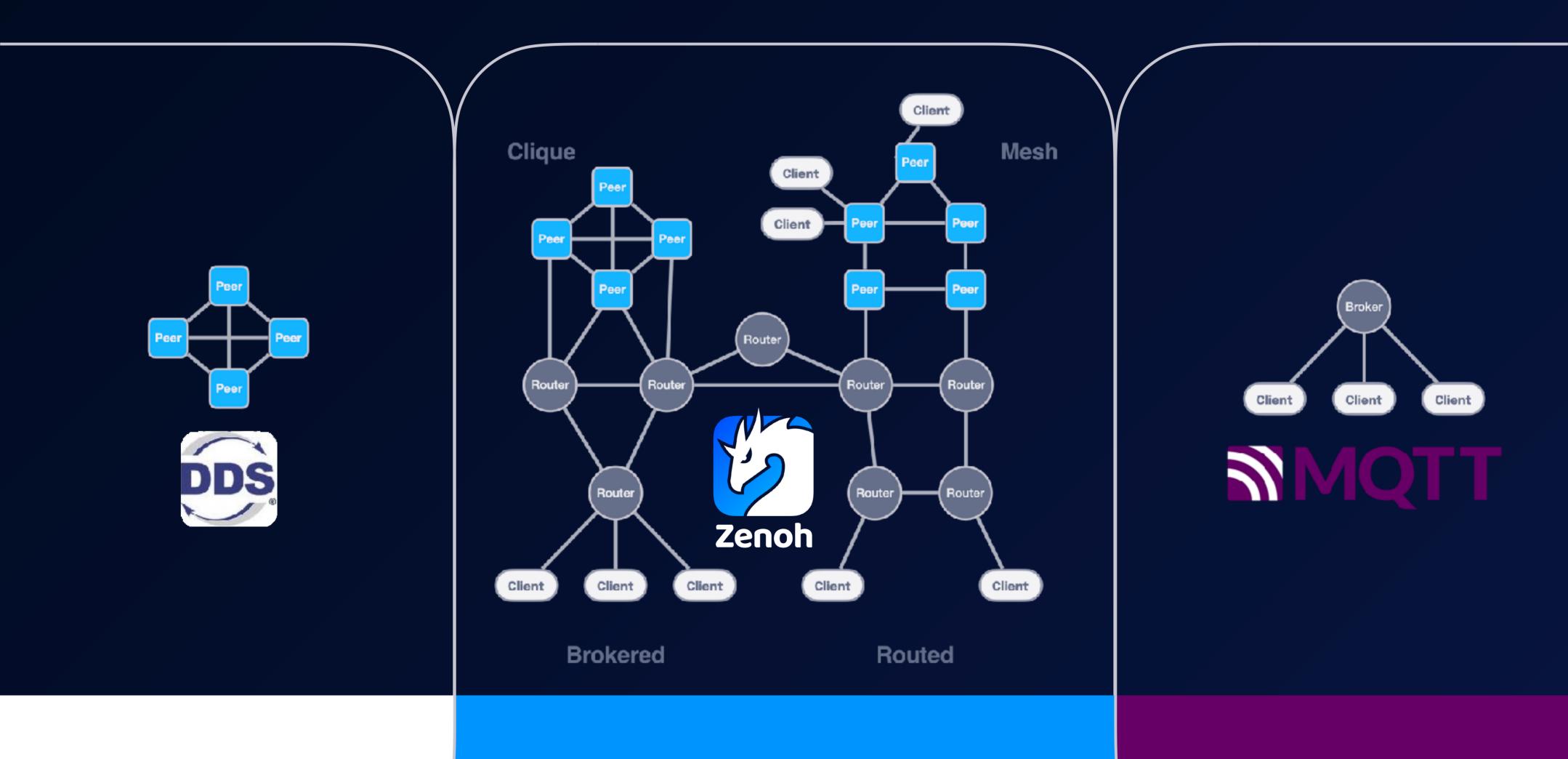




Brokered

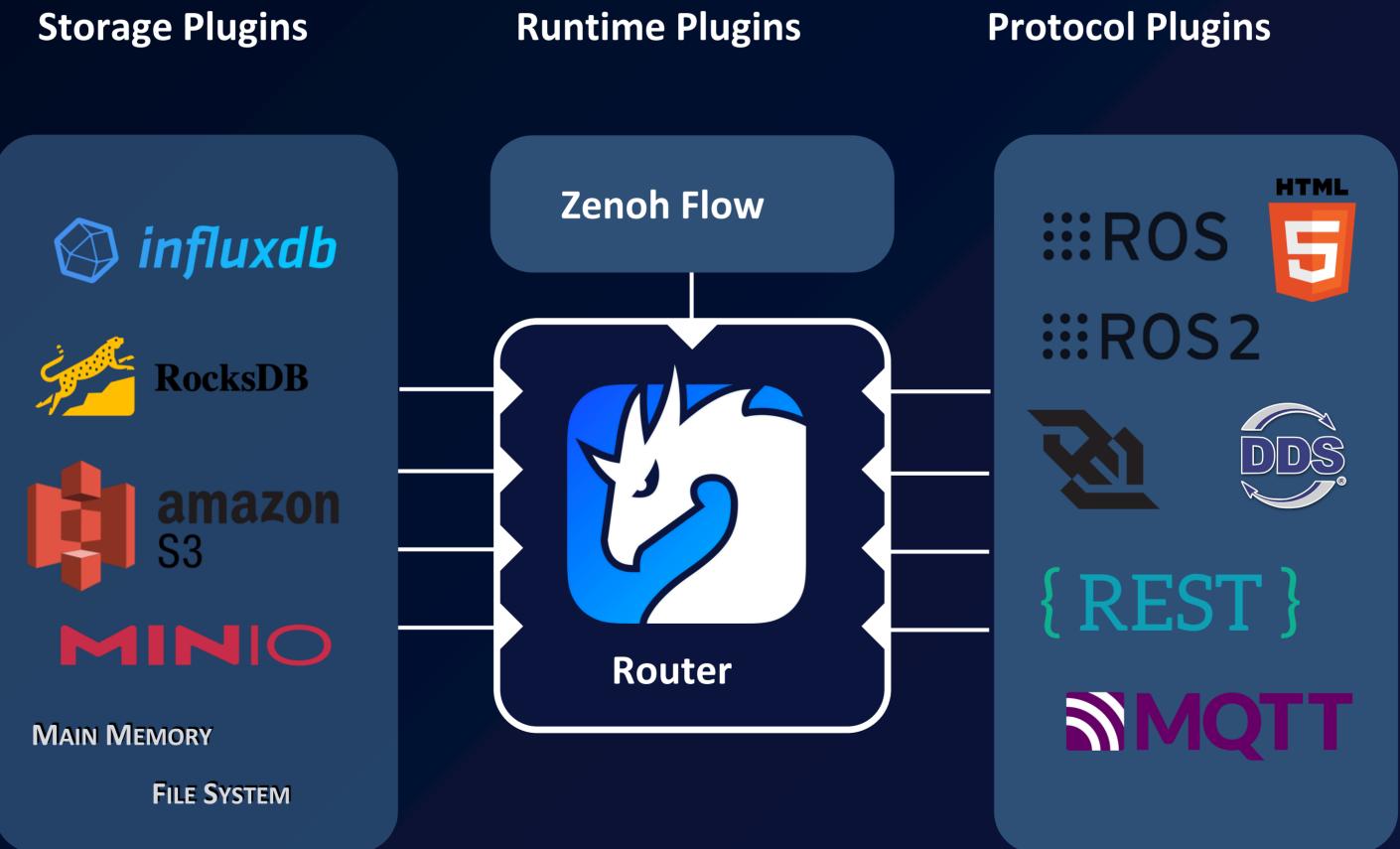
Routed

Topology in Perspective





Plug-Ins





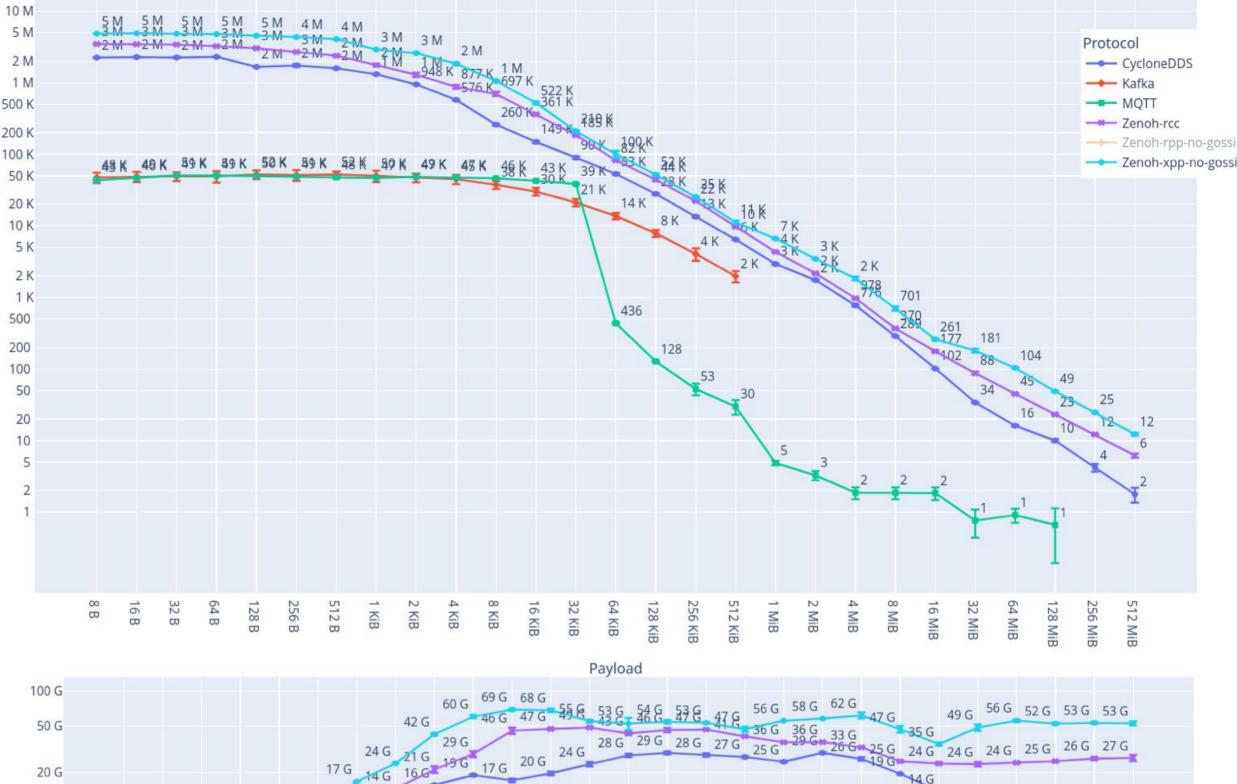
Zenoh vs DDS, MQTT & Kafka

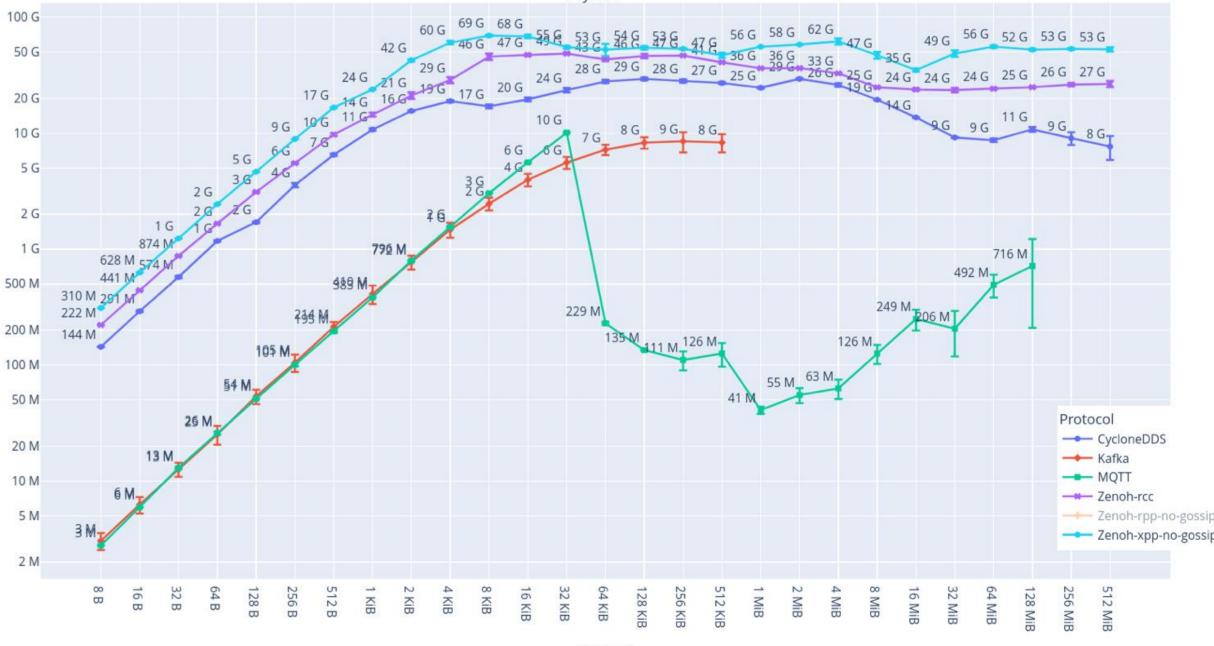
Zenoh can deliver at peak performance of ~70Gbps at 8Kb payload:

- 3.3x higher than DDS
- 23x higher than Kafka
- 35x than MQTT (higher for larger payload)

Zenoh's latency 10us, 6us with ultra-low latency support

- 25us for MQTT
- 75us for Kafka
- 8us DDS





Payload

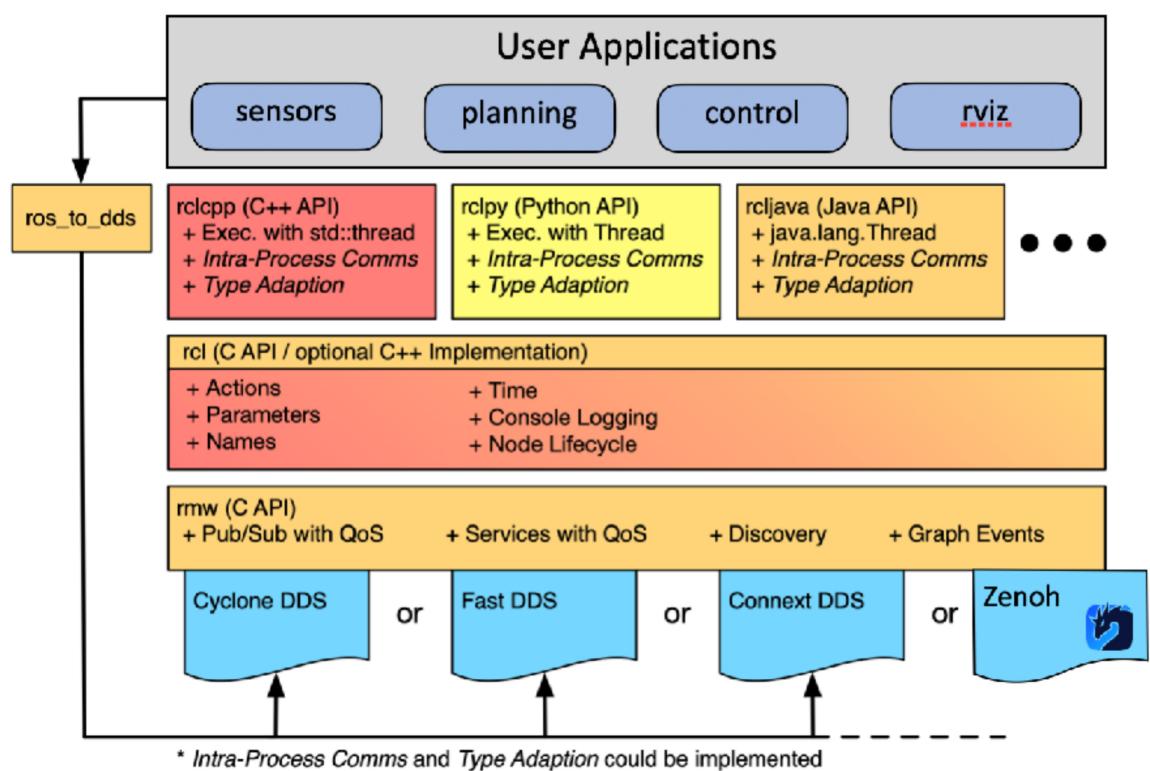
rmw_zenoh

An RMW implementation based on Zenoh





ROS 2 – Modular Architecture



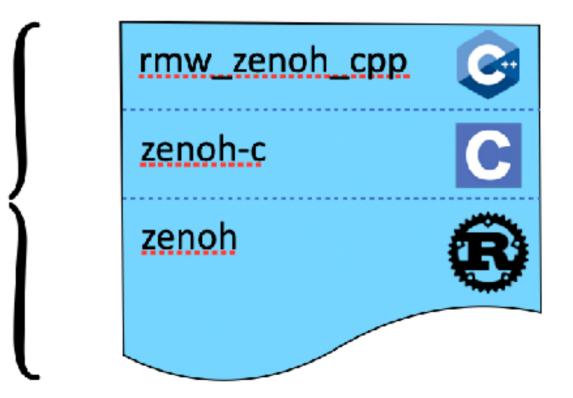
in the client library, but may not currently exist.

https://docs.ros.org/en/rolling/Concepts/Advanced/About-Internal-Interfaces.html#internal-api-architecture-overview

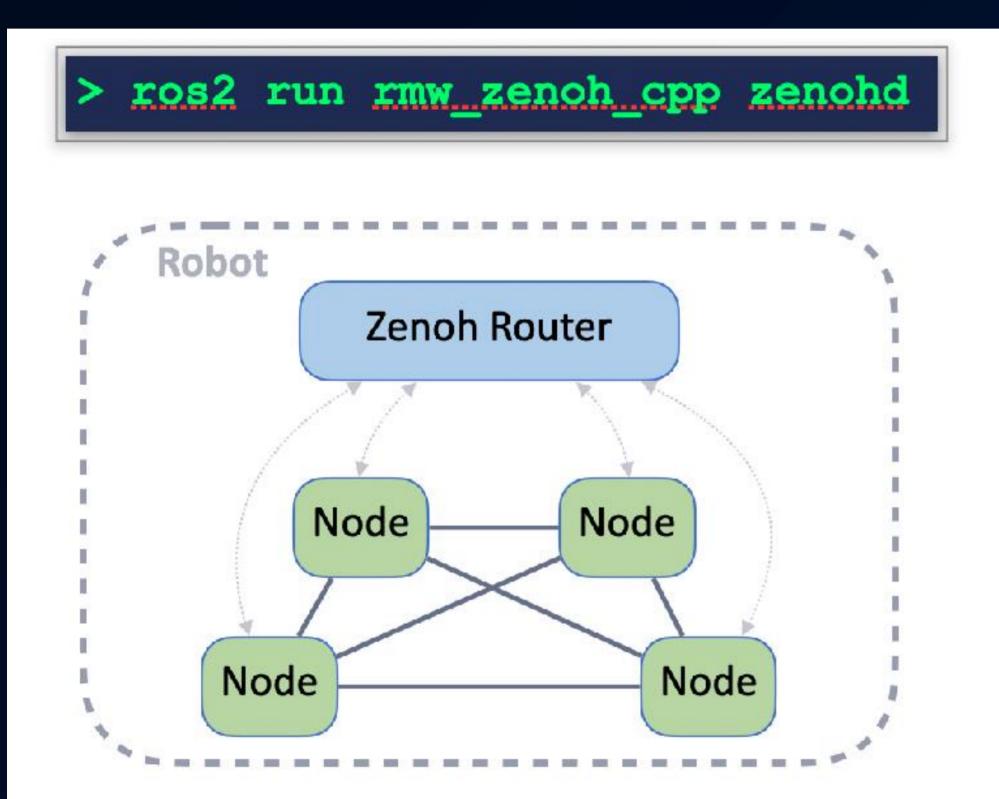




https://github.com/ros2/rmw_zenoh



Zenoh Router



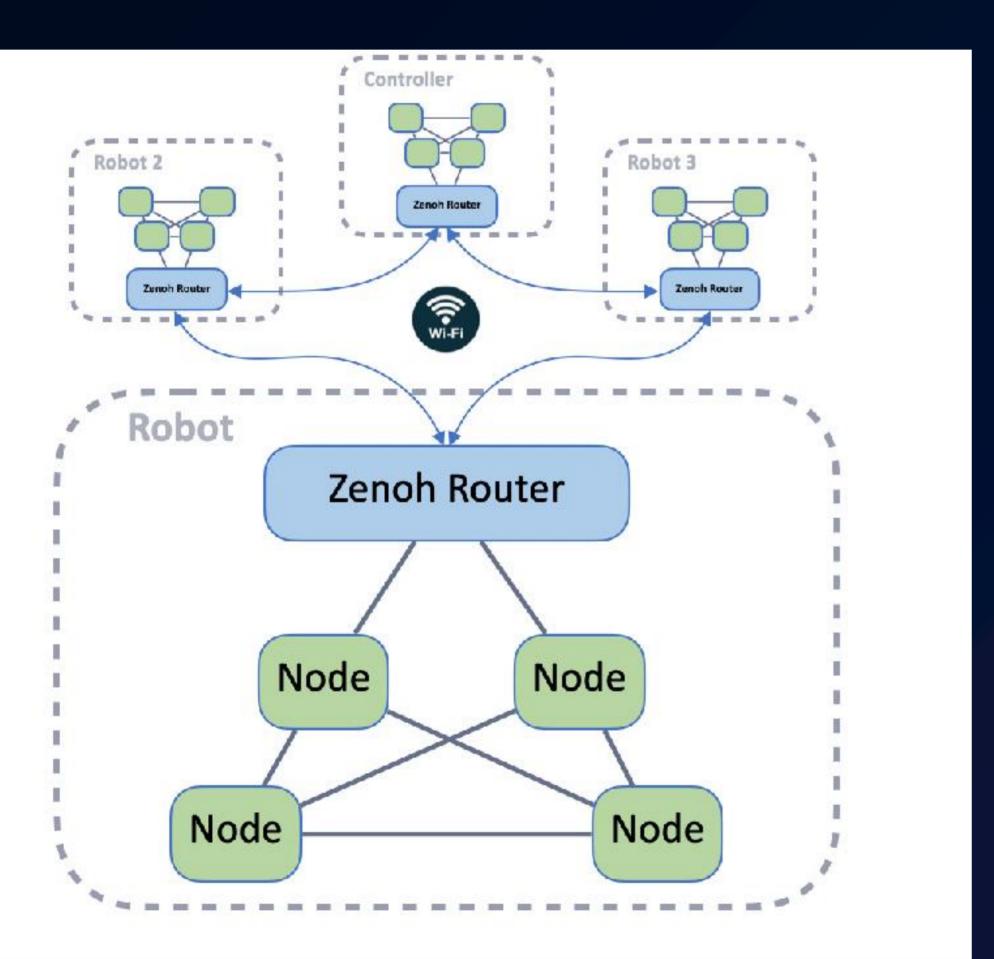
Endpoints Gossip discovery via the loopback
 Peer-to-peer communication via the loopback



Local Communication

- The router listen on tcp/0.0.0.0:7447
- Each Node connect to the router on tcp/ 127.0.0.1:7447
- The router acts as a broker for endpoints discovery
- Nodes establish peer-to-peer connections via 127.0.0.1
- Select the transport for local communication independently than that for R2X
- Leverage SHM Optimisation (coming up)

Zenoh Router



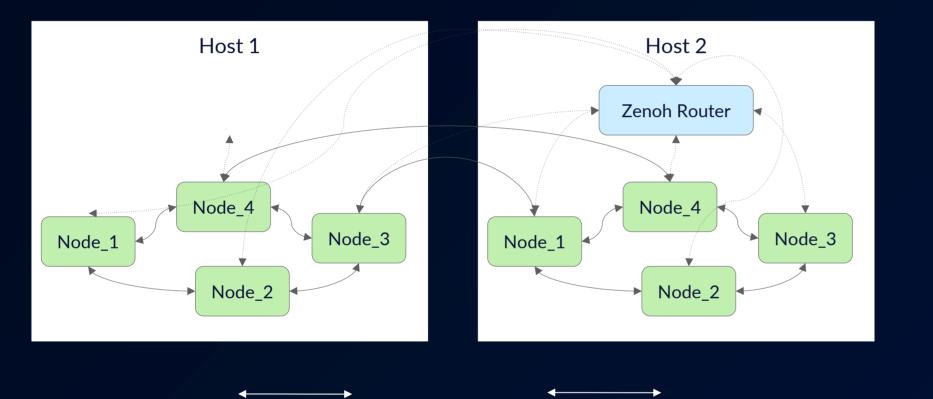


External Communications (R2X):

- May use different transport for R2X, i.e. TCP, TLS, QUIC, etc.
- Transparent Batching and compression
- Access Control and Downsampling
- Smaller surface of attack

Other configurable topologies

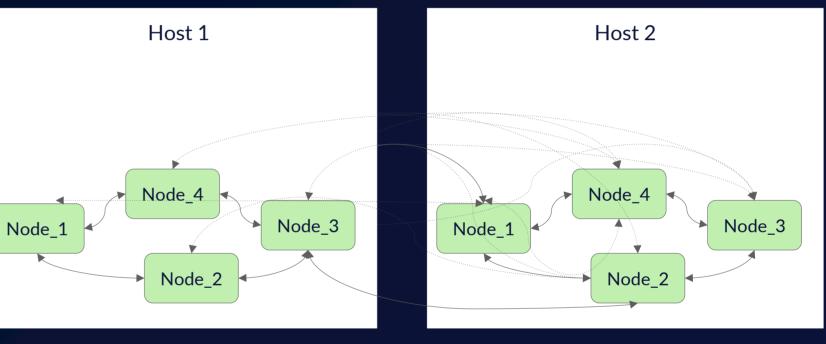
https://github.com/ros2/rmw_zenoh



TCP Discovery

TCP Transport





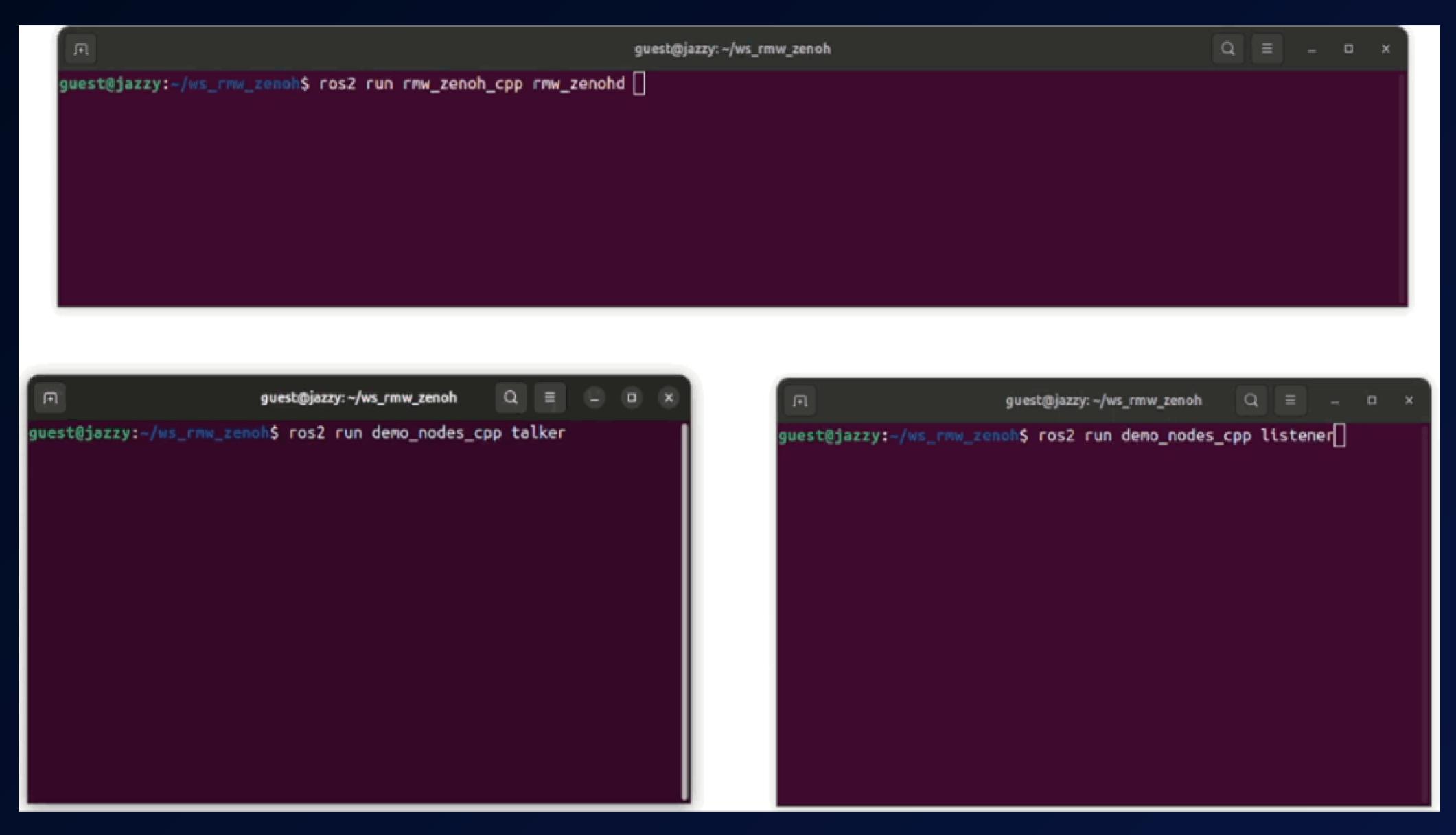




Router for discovery, but peer-to-peer communications



If router crashes, peer-to-peer communications remain

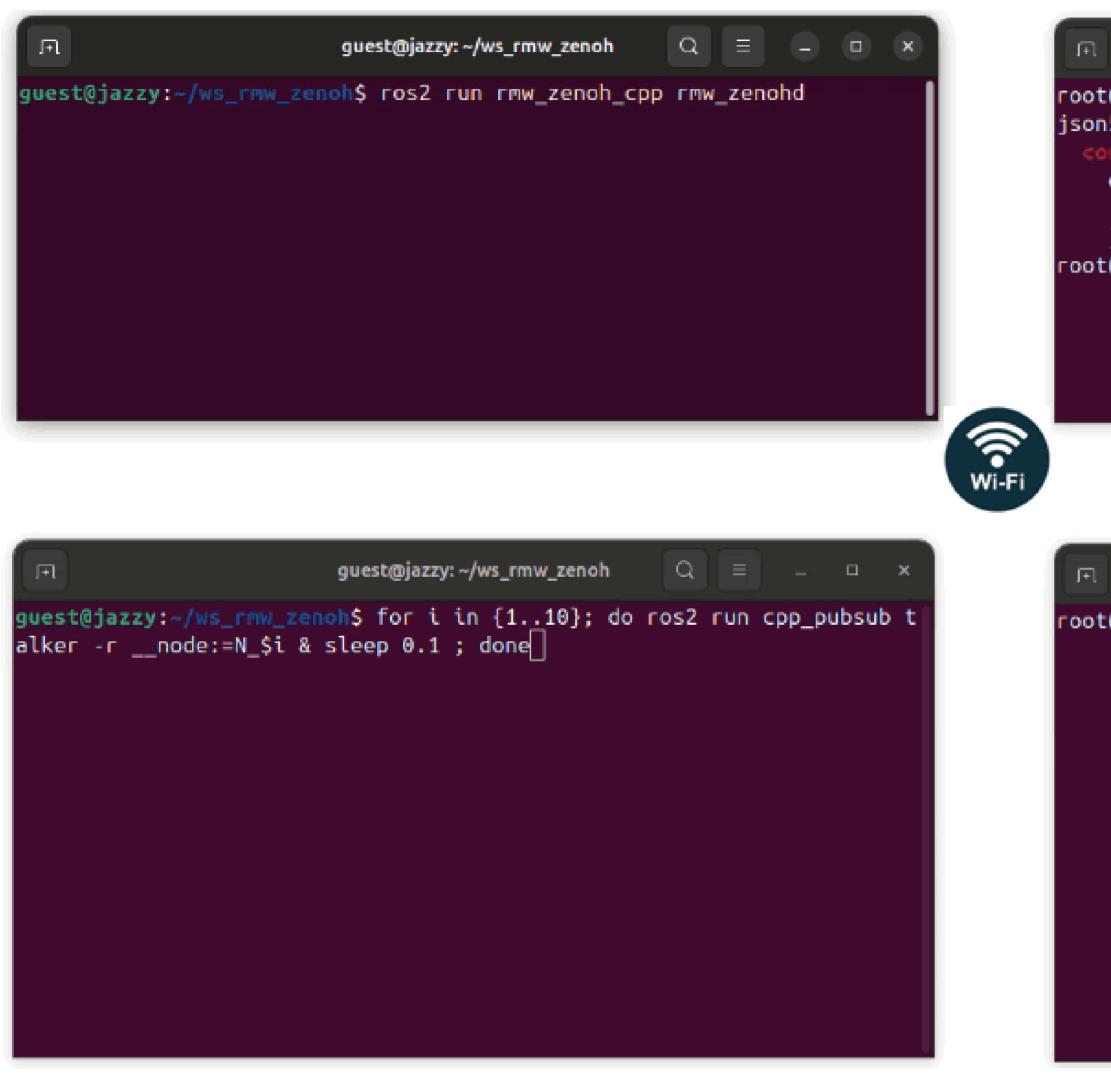


Discovery is robust





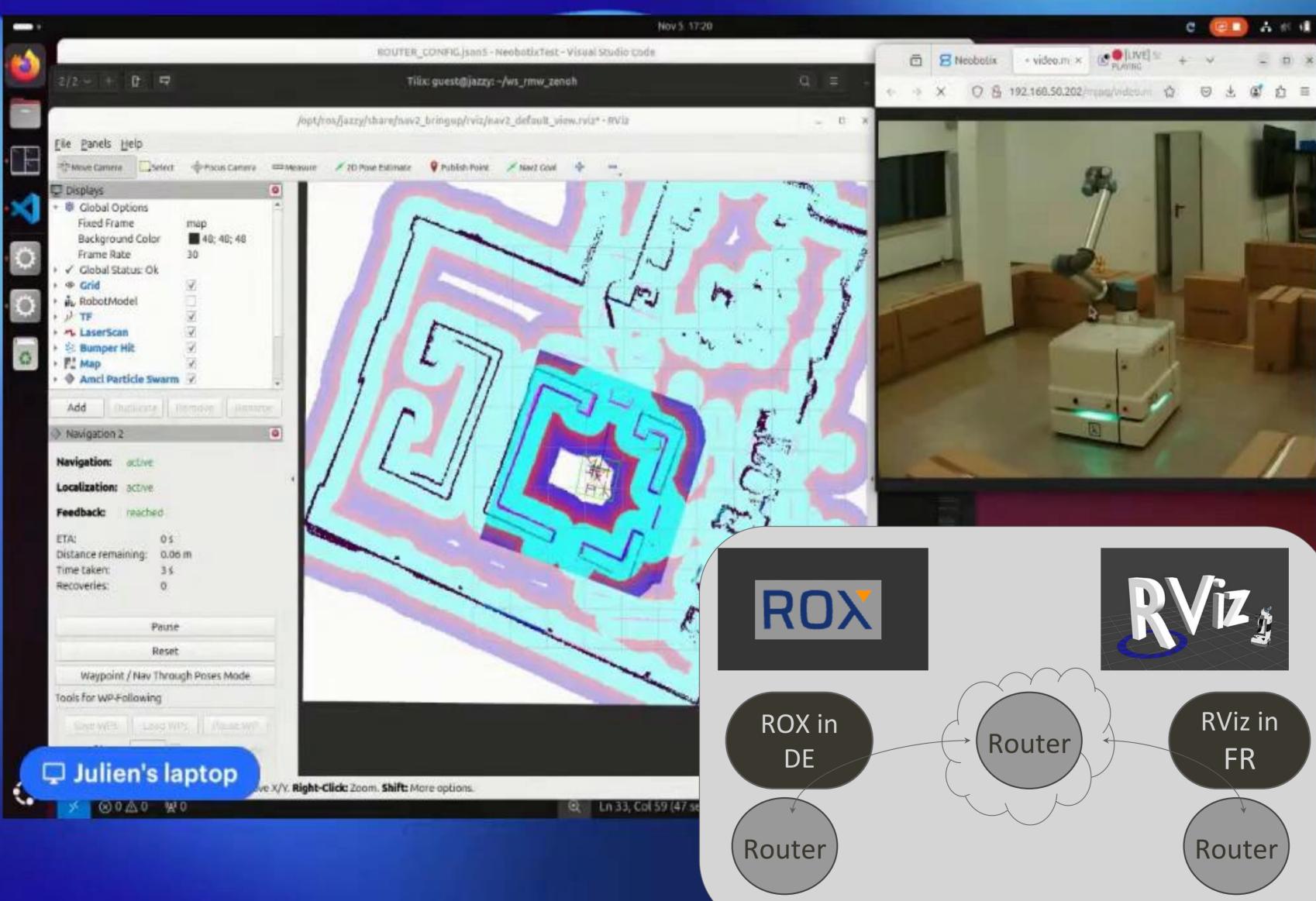
10 Nodes, 1000 Topics discovered in less than 1s over WiFi



			_
	root@colima: /ros_ws	Q = -	ο × ΄
<pre>@colima:/ros_ws# grep - 5 nnect: { endpoints: ["tcp/192.200.40.12:74], @colima:/ros_ws# []</pre>		zenoh_confs/ROUTER	_CONFIG.
	root@colima: /ros_ws	Q = -	o x
@colima:/ros_ws# ros2 t	topic listno-d	aemon	

Transport reliably over many network hops



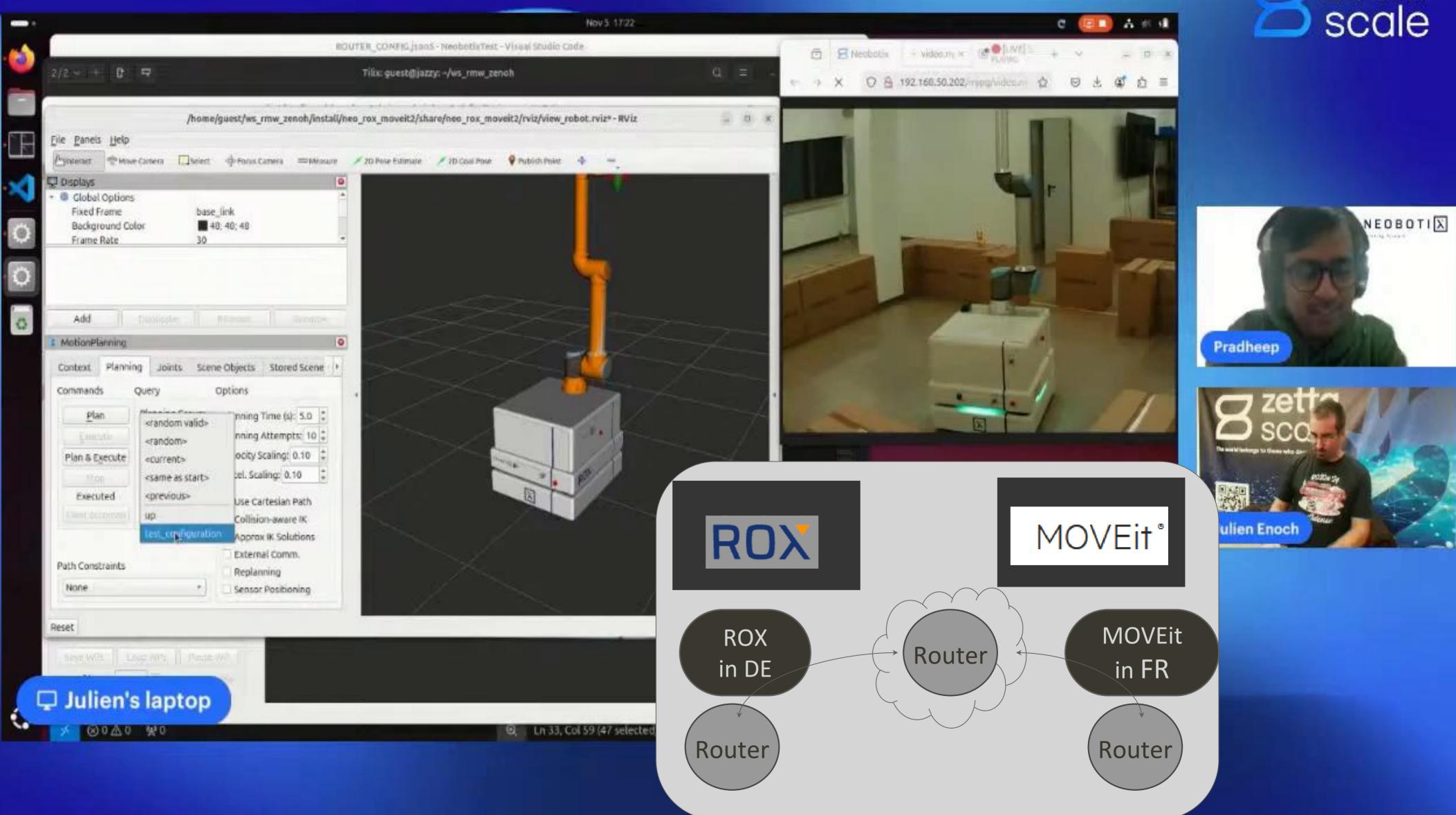








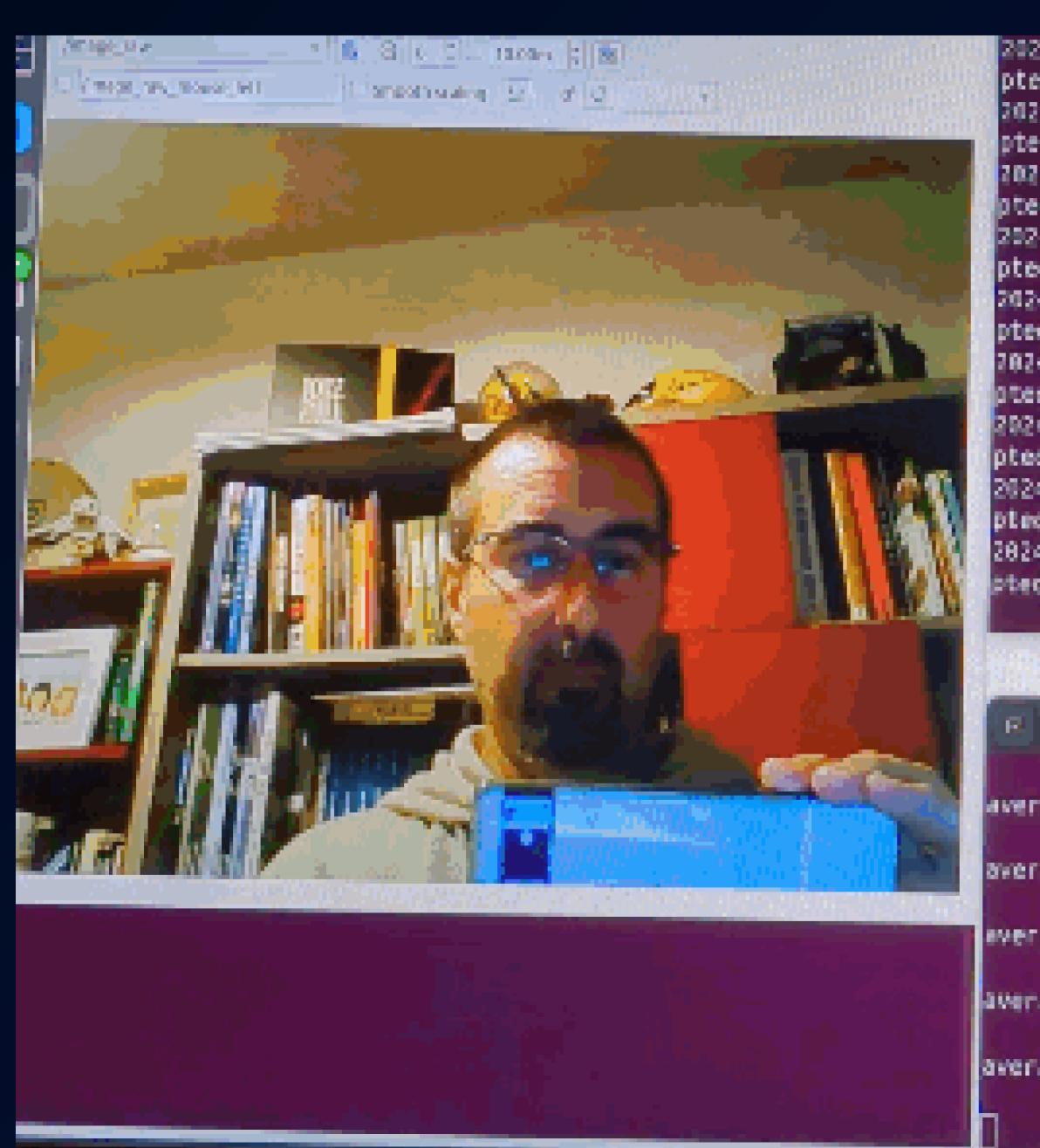






Downsample when needed





pted TEP connection on [::fffff:127.0.0.1]:7447: [::ffff:127.0.0.1 2024-10-16T18:56:52.7704492 CEBUS acc-0 ThreadId(04) zenoh_link_t pted TCP connection on [:::ffff:192.208.40.12]:7447: [::ffff:192.3 2024-16-16T18:56:55.2628292 CEBUS acc-0 ThreadId(04) zenoh_link_t pted TCP connection on [:::fffff:127.8.8.1]:7447: [::ffff:127.8.8.] 2024-10-16T18:56:59.265744Z CENC acc-0 ThreadId(04) zenoh_link_1 pted TCP connection on [::ffff:127.8.8.1]:7447: [::ffff:127.0.8. 2024-10-16T18:57:03.267460Z DEBUC acc-0 ThreadId(04) zenoh_link_ pted TCP connection on [:::ffff:127.8.8.1]:7447: [::ffff:127.0.0.: 2024-10-16T18:57:07.269792Z DEDC acc-0 ThreadId(04) zenoh_link_ pted TCP connection on [:::ffff:127.8.8.1]:7447: [::ffff:127.8.8.: 2024-18-15T10:57:11.2755692 DID.G acc-0 Thread1d(04) zenoh_link_ pted TCP connection on [::fffff:127.0.0.1]:7447: [::ffff:127.0.0.] 2024-10-16T10:57:15.2792902 DEBLG acc-0 ThreedId(04) zenoh_link_ pled TCP connection on [::fffff:127.0.0.1]:7447: [::ffff:127.0.0. 2024-10-16TLB:57:19.202012Z CESUS acc-0 ThreadId(04) zenoh_link_ pted TCP connection on [:::fffff:127.0.0.1]:7447: [::ffff:127.0.0.

		grant (giberry) - vive, states)									
age	min: 0.0325 mex: rate: 30.136	0.0355	std	dev:	8.00151s	window:	20				
ağe	min: 0.027s max: rate: 30.026										
age	min: 0.020s mex; rate: 30.140										
	win: 0.029s max: rate: 29.885										
ige	min: 0.017s max: rate: 29.945	0.6595	std	devs	8.889245	window:	28				
	min: 0.030s max:	0.637s	std	dev:	8.69100s	window:	28				

Known limitations

- . rclcpp::shutdown() must explicitly be called before program termination.
- . Router must be manually started (for now).
- Liveliness and deadline QoS events not supported.



Thank You

Patience, persistence and perspiration make an unbeatable combination for success.





