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How 5G Edge is being used to solve customer problems

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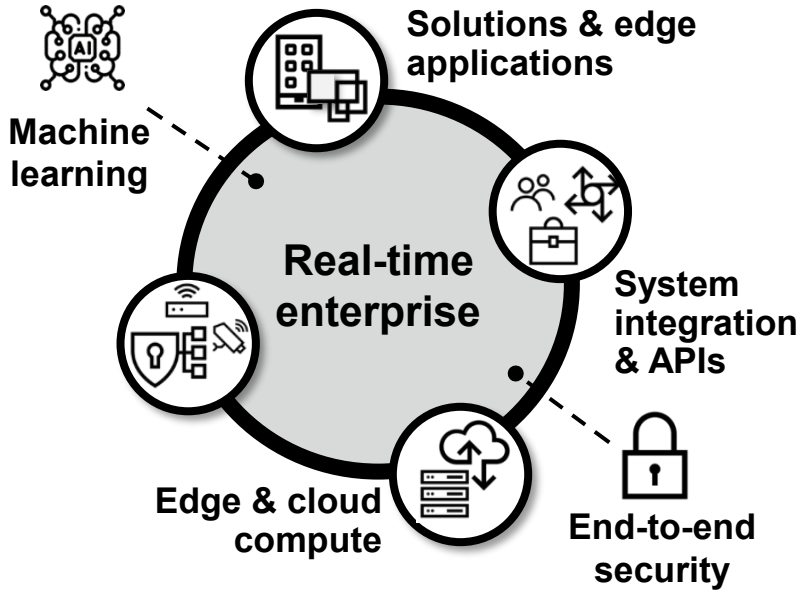
The real-time enterprise powered by the 5G Edge

fourth industrial revolution
Real-time enterprise (RTE)



Today
Edge computing





- **Enablement of end-to-end visibility and control from production to consumption**
- Empowers **people, devices, and systems to interact** efficiently and safely in a **highly automated environment**
- Leverage **5G/MEC and 4G LTE** capabilities

Built on strategic technology investments

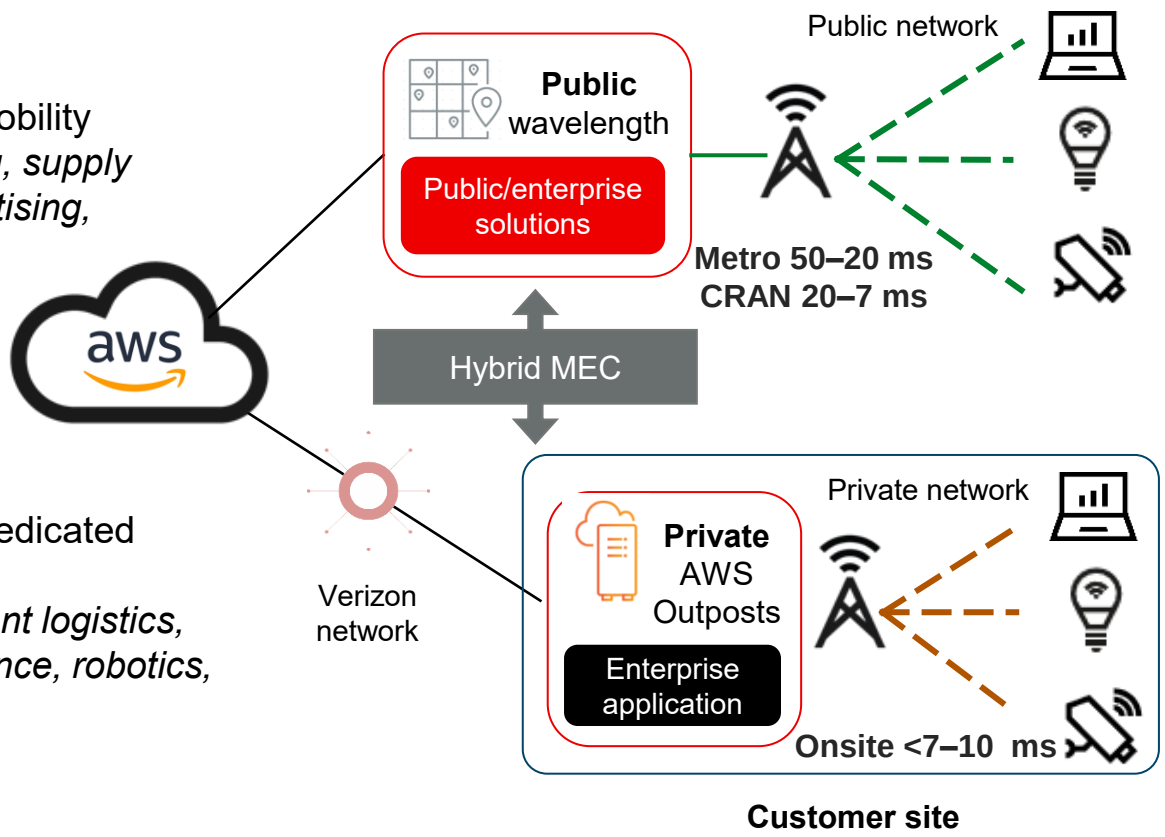
Fiber	**C-band + mmW spectrum**	**SDN – Software-defined networks**	**MEC – Mobile edge compute**

5G Edge: Ultra-low latency from application to endpoints

Multi-access edge computing (MEC) enables cloud servers to run closer to endpoints, reducing latency and speeding local processing. Think of having the cloud in your back pocket.

Public MEC
- Multitenancy with mobility
- ***Use cases****: Gaming, supply chain, media, advertising, retail, venues*

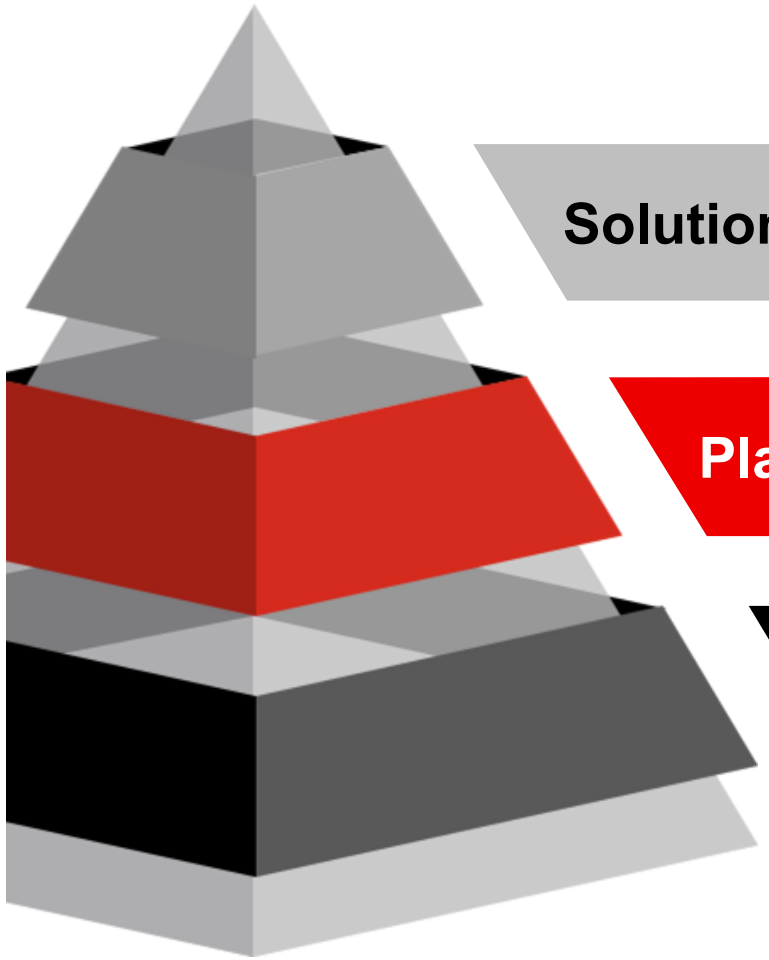
Private MEC
- Single tenant with dedicated private network
- ***Use cases****: Intelligent logistics, predictive maintenance, robotics, factory automation*



Differentiators

- Provide developers access to **120M+ connections across 19 metros**
- **Ubiquitous mobility** across public and private networks
- Extensive **strategic spectrum** holdings
- **Densified SAP/CRAN** for edge cloud
- **Common control plane** managed from the cloud
- Same AWS **APIs and tools** as in the AWS Region

MEC framework



Solutions

VZ solutions | 3rd party | Developer ecosystem

Platform

VESA – Common construct & API layer

MEC

Connectivity

4G/5G mobility and private networks

Current customer challenges managing edge infrastructure



Security

- Predefined customer, ISV, SI security policies
- Hardened delivery infrastructure
- Integrated 5G + SDN security services



Interoperability

- Device- and network-aware–based orchestration
- Catalog of pre-integrated edge solutions
- Hybrid cloud resource deployments at scale



Complexity

- Common deployment automation across edges
- Catalog of PaaS services with solution builder
- End-to-end design, implementation, and support



Performance

- Leader in low latency, high-performance networks
- Network-aware edge AI driving real-time decisions
- End-to-end performance management

5G Edge solutions

Venues & retail

Crowd analytics

Understand venue visitor movement and occupancy to optimize operations, safety, and security

Cashierless checkout

Increase customer satisfaction by eliminating checkout wait time – Help drive higher sales per square foot

Accelerated physical access*

Expedite access to controlled areas for VIPs and authorized visitors

Manufacturing & transportation

AGV management

Provide AGV controls and image analytics for warehouses and factory floors

QA for production

Enable quality improvement via insight into all aspects of production processes

QA for warehousing

Use computer vision and inventory control to automate the manual warehouse QA/QC process

Industrial analytics*

Predict and manage yield and machine performance – Reduce downtime and costs

Inventory management*

Use intelligent automation to increase effectiveness of enterprise warehousing, distribution, and logistics ops

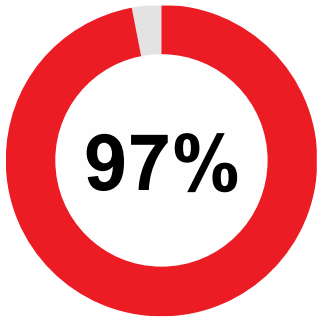
Verizon 5G Edge solutions help organizations maintain safety, manage costs, and enhance customer experiences

AGV: automated guided vehicle
QA: quality assurance

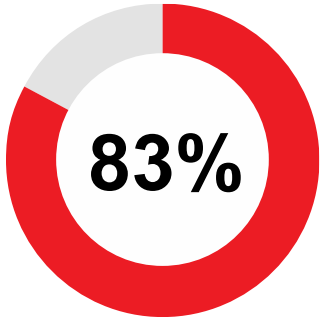
Crowd Analytics is commercially available. Other solutions are precommercial solutions, features and timing subject to change.
Verizon makes no representation that it can or will provide the precommercial solutions depicted above at any specific time in the future or at all.
* Placeholder names—not approved by Naming and IP Legal

Deep dive:
Cashierless checkout

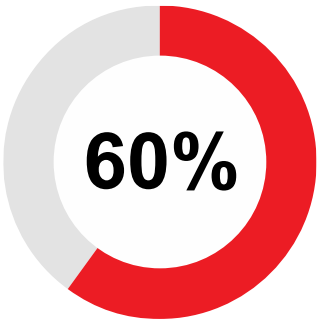
Customer demands continue to disrupt the market and drive the need for innovation



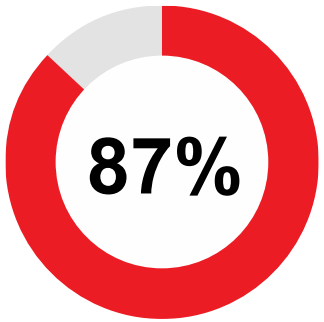
of consumers have backed out of a purchase because it was inconvenient to them[1]



of consumers say convenience while shopping is more important now compared with 5 years ago[2]



consider long lines for payment checkout as a leading pain point when shopping in a store[3]



of shoppers prefer in-store touchless or self-checkout options[4]

1 "Convenience and the Consumer," NRF, Jan 2020. nrf.com/consumerview/Capgemini.
2 "Frictionless Commerce 2020, How Coronavirus Is Accelerating Seamless Omnichannel Retail," eMarketer, May 2020.
3 "Smart Stores: Rebooting the retail store through in-store automation," Aug 23, 2020. https://smartstores.com/smart-stores-rebooting-retail-through-in-store-automation/
4 "87% of Shoppers Prefer to Shop in Stores with Touchless or Robust Self-Checkout Options During COVID-19 Pandemic," Bloomberg, Apr 7, 2020.

Partnering with the largest autonomous retail platform

AiFi is the largest computer vision platform that empowers businesses to scale with industry-leading AI solutions



100+
active stores around the globe

20+
global retailers signed contracts

$65M
series B funding

16
retail and industry investors

Simplifying the customer journey



EASY ENTRY

Shoppers can enter the store quickly with their credit card or an app

SEAMLESS SHOPPING

AI-powered computer vision begins anonymized shopper tracking and recognizes products taken

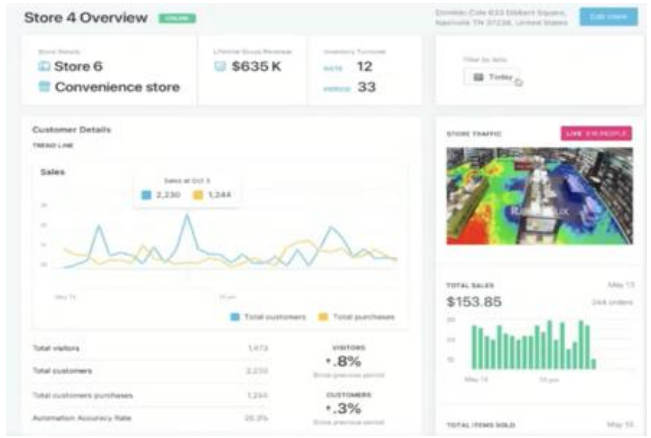
FRICTIONLESS CHECKOUT

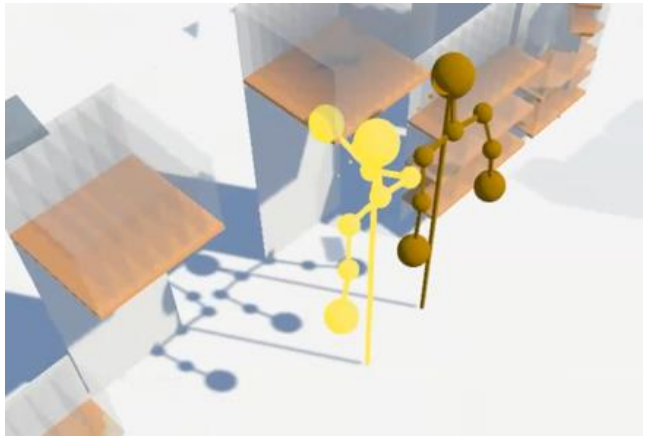
Shoppers can head home completely checkout-free with receipts sent directly to their emails if selected

Autonomous retail: Three value drivers









1 CUSTOMER CONVENIENCE

Quick and easy shopping

Available 24/7

Inventory availability

2 OPERATIONAL EFFICIENCY

Customer analytics

Staff task automation

Additional retail space

3 LABOR OPTIMIZATION

Reskill

Repurpose

Restaff

A platform that scales

4 COMPONENTS THAT ANSWER:

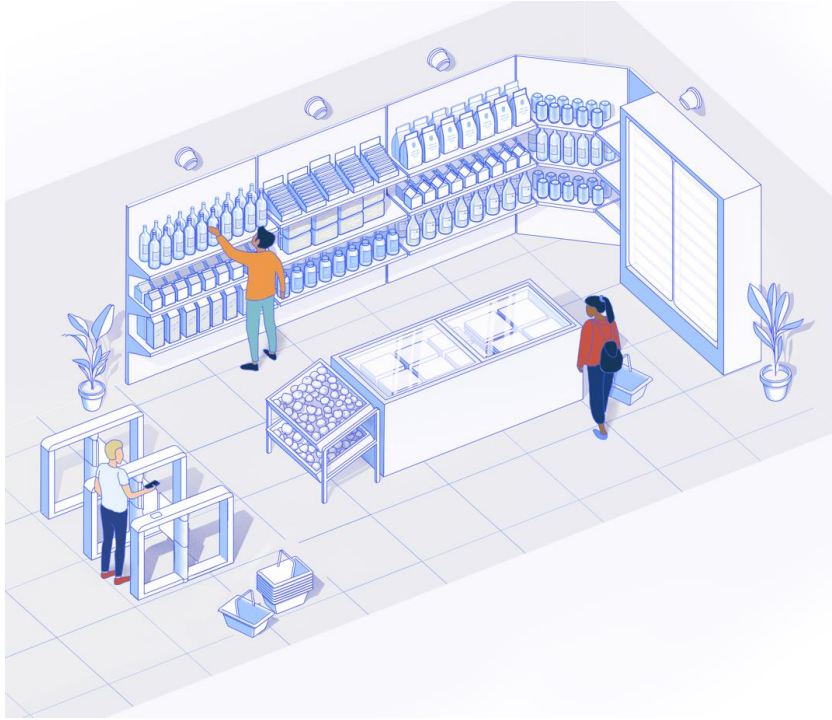
"WHO GRABS WHAT WHERE?"

COMPUTER VISION
Enables scalability

ENTRY SYSTEMS
Allow flexibility

DATA PROCESSING
Increases affordability

OPERATING SYSTEM
Provides efficiency



Computer vision

Scalable technology with 100% cameras only



Flexibility and affordability

- No weight sensors allow greater flexibility and lower overhead costs
- Scalability from 200 sq. ft. up to 7,000 sq. ft.
- Higher tracking flexibility across multiple product categories, including but not limited to
  - Fresh produce
  - Prepared foods
  - Bakery
  - Soda & coffee machines
  - Merchandise
- **Privacy by design**

- 100% anonymized keypoint tracking technology
- No use of facial recognition or biometrics
- Customer privacy

Data processing

Connectivity with low GPU utilization



Server and network cost reduction

Servers used reduce upfront hardware costs and network connection speed requirements

- Less than 1,000 sq. ft. = 25 mbps
- Greater than 1,000 sq. ft. = 50 mpbs

5G + verizon MEC technology

Eliminates the need for servers, offering

- Immediate upfront hardware savings
- Greater space utilization

Entry system

Flexibility and customization

Hardware flexibility

•Turnstiles for gated entry
•Free-standing kiosks for open or hybrid entry

Entry customization

•Branded or white label app
•Credit card
•Combination of app and card





Operating system

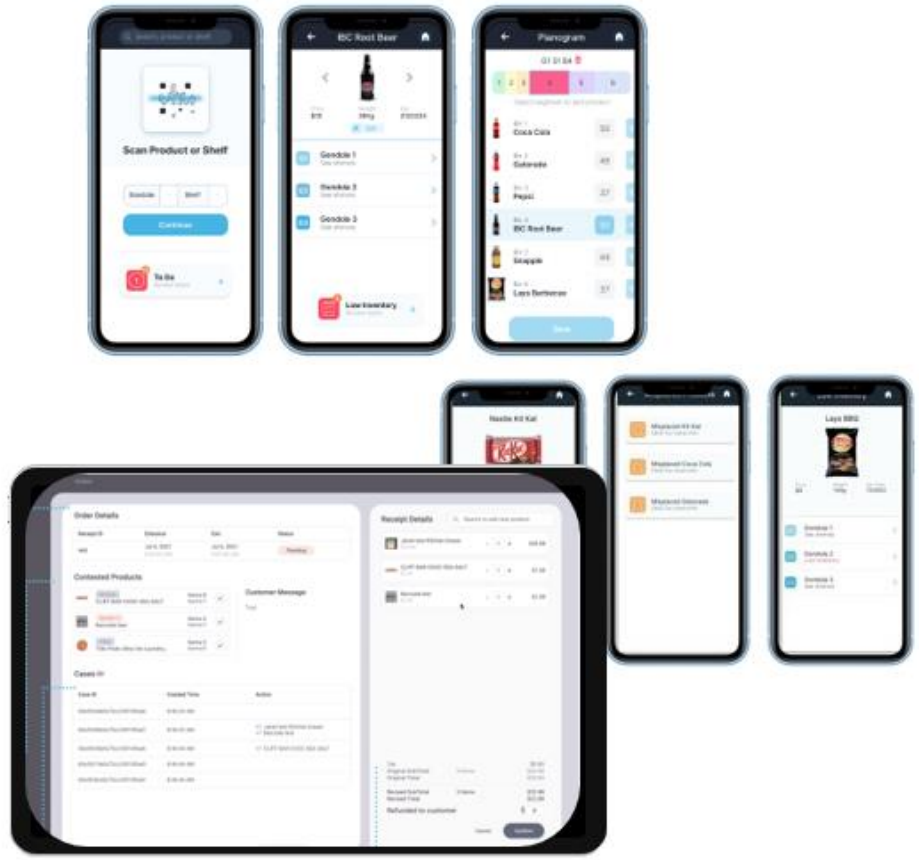
Tools for maximum control and efficiency

1 Operations app

Staff quickly manage
- Products
- Inventory
- Planogram

2 Store management portal

Store operators easily audit
- Order details
- Customer receipts



Case study: Detroit Lions



	DOWNTOWN COUNTER Lions vs Packers (12/29/19)	VERIZON EXPRESS SHOP Lions vs Packers (01/09/22)	% CHANGE
Event Attendance	57,338	48,969	15% ↓
Average Item Price	$10.18 *(with alcohol in planogram)*	$7.59 *(no alcohol in planogram)*	25% ↓
Store Revenue	$5,482 *($0.10 Per Cap)*	$13,121 *($0.27 Per Cap)*	139% *(170%)* ↑
Basket Size	1.44	2.59	80% ↑
Total Transactions	374	667 *(1,846 unique shoppers)*	78% ↑
Transactions Time ***(minutes)***	2:48*	1:18* *(repeat customers < 0:24)*	1:30 ↑

* 2019 Season = Measured by time between consecutive transactions at one point of sales, at peak period; 2021 Season = Measured by total time spent in store (inclusive of numerous fans browsing). This shows that the frictionless store (inclusive of queuing, browsing, fulfilment, and payment) was more than 90 seconds faster than just a transaction at traditional belly-up stands.

Case study: Monster Jam



	DOWNTOWN COUNTER Monster Jam Event (3/09/2019 – 3/10/2019)	VERIZON EXPRESS SHOP Monster Jam Event (02/26/2022 - -2/27/2022)	% CHANGE
Event Attendance	88,064	88,833	1% ↑
Average Item Price	$5.03 *(with alcohol in planogram)*	$6.37 *(with alcohol in planogram)*	27% ↑
Store Revenue	$6,567 *($0.07 Per Cap)*	$17,441 *($0.20 Per Cap)*	166% *(186%)* ↑
Basket Size	2.69	3.93	46% ↑
Total Transactions	485	697 *(2,102 unique shoppers)*	44% ↑
Transactions Time ***(minutes)***	2.38*	1:54* *(repeat customers < 0:16)*	0:44 ↑

* 2019 = Measured by time between consecutive transactions at one point of sale, at a peak period; 2021 = Measured by total time spent in store (inclusive of numerous fans browsing). This shows that the frictionless store (inclusive of queuing, browsing, fulfilment, and payment) was more than 44 seconds faster than just a transaction a traditional belly-up stand.

Deep dive:
Distributed databases



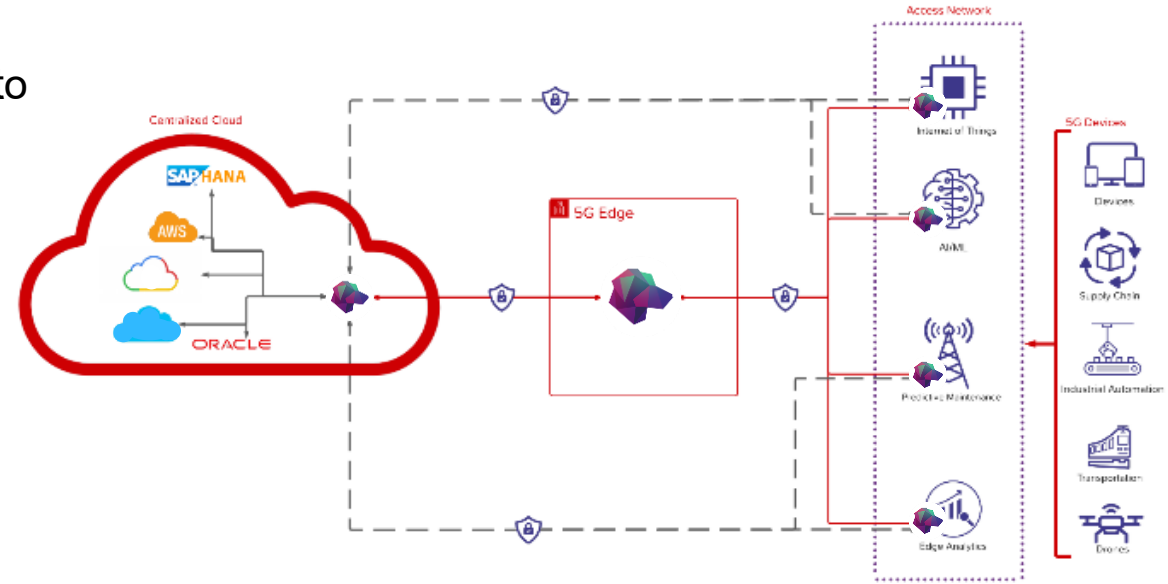
Driving near real-time performance

Problem

- Databases are not designed to scale horizontally and cannot be decoupled from the cloud provider
- Centralized, monolithic cloud-based data storage is slow to converge on near real-time data value
- Bottlenecks between edge/5G and cloud
  - Gap between IoT data collection and the cloud
  - Lack of security

Solution

- Using AWS Wavelength along with both a Node.js and TensorFlow
  - Bring data persistence and APIs closer to the source
  - Eliminate gaps between IoT data collection and cloud
  - Enable real-time data sync for IoT and edge analytics
  - Utilize edge distribution to eliminate bottlenecks and increase security



Introducing HarperDB to the equation

A fast, flexible platform for distributed applications and data

- **Read/write optimized**
  - 20K writes/second, 120K reads/second for a single node
  - Non-blocking writes: Performant queries under load
  - Built on LMDB's lightning fast key-value store
- **Integrated HTTP interfaces**
  - Core operations API
  - Custom functions API for user-defined endpoints
  - Powered by Fastify and its rich ecosystem
- **P2P/mesh intranode replication**
  - Global replication in 100 ms
  - Pub/sub moves the data only where you want it
  - Fault-tolerant delivery handles network outages
- **Custom functions**
  - User-defined endpoints with direct access to storage tier
  - Projects can be powered by npm and tracked in your VCS
  - Runs as its own process independent of operations API
- **Easy to architect**
  - Schemaless design, like a document store
  - SQL semantics to join tables, like an RDBMS
  - Auto-indexed by default for performance out of the box
- **Easy to scale**
  - Linear capacity-to-cost ratio
  - Flexible deployment: Docker, Kubernetes, SaaS, managed
  - Tiny application footprint, works with block storage



Golf experience presented by Verizon

Golf Experience presented by Verizon | Your game. Your way.







Golf Experience presented by Verizon is currently rolling out nationwide





EDISON INTERACTIVE

Club Car®

Solution

- Verizon-branded product
- 4G LTE rugged tablet with BT speakers
- Cart telematics and cart control
- Yahoo news, sports, and finance content
- Third-party content integration
- VZ AdTech and programmatic advertising
- Tune-in streaming music
- Golf tips
- Hole flyovers and distance to hole

13M	425	40K
rounds played +18% YTD	courses contracted +24% YOY	carts connected +17% YOY

The challenge

33K golf carts

60+ third-party API calls

5 second peak latency

Origin APIs were verbose, transmitting unnecessary data

Endpoints were hard-coded into each tablet, making code rolls a massive pain

Desire for ML-enabled coaches, etc. wouldn't run on hardware as it was



The solution

Create distributed API cache

Move origin API calls on to Verizon 5G AWS Wavelength servers with HarperDB custom functions

Shape the data returned from the origin API to reduce payload size

Persist the shaped reply to HarperDB

Return the cached result when not expired

Use HarperDB clustering to replicate cache results to all AWS Wavelength servers



The results

250x faster

Greater stability

Reduced code rolls

20 ms response times for cached responses

Cached responses **cover third-party point of failure**

Reduced device processing extended effective life of tablet hardware

Extremely low latency **enables server-side recommendation and classification ML services**



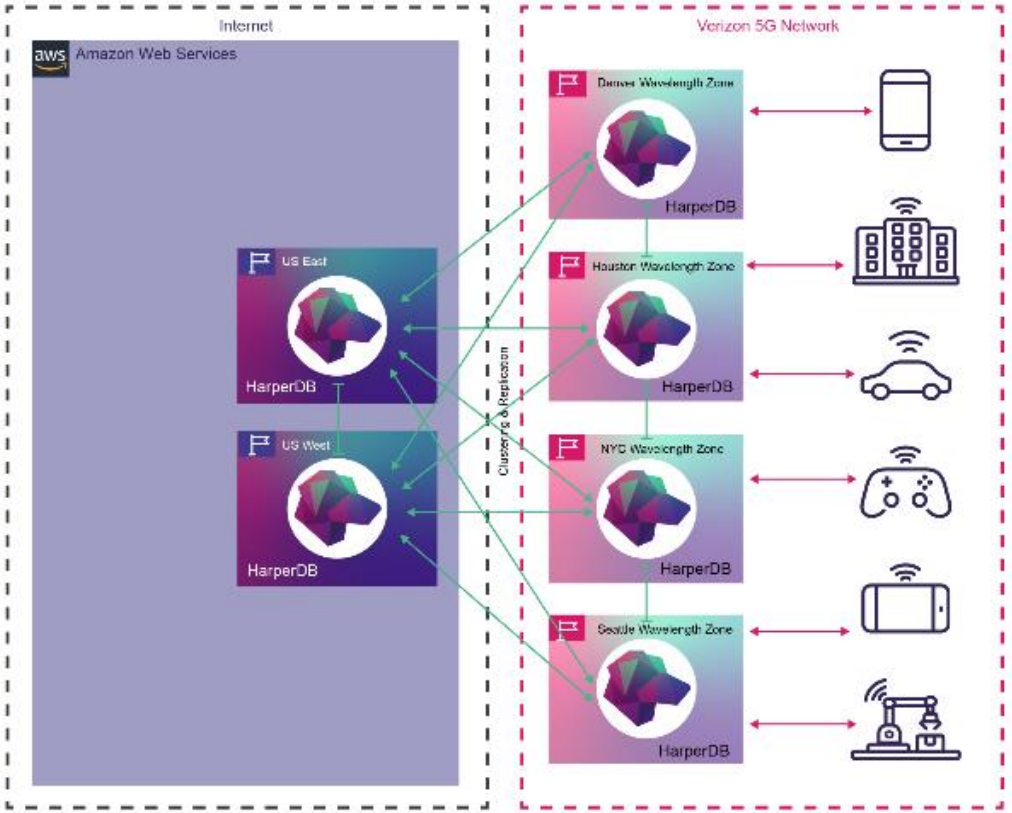
HarperDB running on Verizon's 5G Edge

Simplicity without sacrifice

- Self-serve PaaS model
- Built on the 5G AWS Wavelength
- 19 Regions around the US… and counting
- 3 server sizes, including GPU-enabled instances
- Server, license, I/O costs are all included

Unparalleled performance and flexibility

- Mobile apps experience near-zero latency
- Replicate data back to public/private cloud
- Sync across multiple 5G wavelength providers
- Global performance with HarperDB/AWS Wavelength



Recap



5G Edge state of the union

Expanding our market reach



19 5G Edge markets launched

Robust private network portfolio

NOKIA ERICSSON

celona

Partnership with leading system integrators

IBM KPMG

Deloitte. Capgemini

Tech Mahindra BOSCH

Growing base of 5G Edge solutions

- Crowd analytics
- Cashierless checkout
- Accelerated access
- AGV management
- QA for production
- QA for warehouse
- Machine analytics

✓

Rolling thunder of customer wins

Virginia International Terminals, LLC

BlackRock.

accenture

NHL

Joint Base Pearl Harbor-Hickam

MOOG

ABP ASSOCIATED BRITISH PORTS

BAYER

NFL

NBA

Thank you!



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