



Delivering the Komatsu Autonomous Haulage System over private LTE

Setting a new
networking standard
for mining automation

Photo: Komatsu

NOKIA

In January 2019, Komatsu announced the mining industry's first Autonomous Haulage System (AHS) running on Nokia Industrial-grade Private Wireless technology. This is enabling ultra-high system availability and reliability across Komatsu's commercial operations, while upholding the company's renowned safety standards.

Today, more than half of Komatsu's production sites in North America, Latin America and Australia are running on Nokia 4.9G/LTE.

Komatsu is a world-leading provider of the essential equipment, systems and solutions used by companies worldwide to extract the fundamental minerals needed for developing modern infrastructure, technology and consumer products.

Komatsu's FrontRunner trucks are based on conventional large mining trucks and run completely autonomously. A full truck fleet can be monitored by a single controller, located thousands of kilometers away, and can be operated 24 hour a day, seven days a week. This approach delivers significant safety, productivity, reliability, performance and operational benefits to mine fleet owners.

Komatsu completed a year-long qualification program at their proving grounds in Sahuarita, Arizona. This included conducting extensive testing of the FrontRunner AHS on Nokia's Future X infrastructure, which resulted in Komatsu acknowledging LTE as a wireless technology of choice for mining automation. They also recognized Nokia as a leading provider of private 4.9G/LTE communication solutions for the mining industry.

Komatsu's FrontRunner AHS allows unmanned operation of the ultra-class mining trucks that are critical to the mining industry. These autonomous haul trucks are centrally controlled through a

wireless network. This integrates on-board vehicle controllers, high-precision global positioning, and obstacle detection and avoidance systems.

The system uses full supervisory logic, harnessing complex data fusion to control the dump truck to safely operate through a load, haul and dump cycle. It also allows integration with other mining vehicles such as light vehicles, dozers, loaders and graders.



Komatsu is an indispensable partner to the mining, forestry, industrial and construction industries. Komatsu provides essential equipment, systems and solutions that are used by mining companies worldwide to extract fundamental minerals in order to develop modern infrastructure, technology and consumer products.

The company conducts research, development and benchmarking for Komatsu mining haul trucks at Komatsu's 660-acre Proving Grounds in Arizona.

Komatsu's FrontRunner AHS brings together the world's best-selling, ultra-class dump trucks with Modular Mining Systems' DISPATCH Fleet Management System. This is the preferred management system in 90% of the largest mining operations in the world.

Komatsu's FrontRunner AHS has experienced exponential growth in cumulative production, since its first commercial deployment in 2008 at Codelco's Gabriela Mistral copper mine in Chile. It has moved more than 3 billion tons to this date.

The company has worked closely with customers to fine-tune safety features, achieving the system's stunning 13-year zero-harm safety and productivity record and unmatched ability to accommodate an array of mining environments. This has enabled Komatsu to accelerate the pace of AHS deployment. It anticipates that through FY2020, Komatsu AHS growth will continue so that more than 350 autonomous trucks will be hauling copper, iron, coal and oil sands at over 15 sites, across three continents.



Photo: Komatsu

Transforming mining operations

The digital transformation of mining has been slow to develop; but it's now making up for lost time and accelerating quickly. Autonomous vehicle technology, internet of things (IoT) sensors and analytics, machine learning (ML) and artificial intelligence (AI) all hold tremendous promise, taking mining automation to the next level.

These innovations will accelerate almost every aspect of mining operation, from pit to port. They have the potential to dramatically improve safety, efficiency and productivity — optimizing operational processes and costs.

Throughout history, miners have looked to improve safety and gain a mechanical advantage by using

heavy machinery to automate tasks such as drilling, blasting, loading, hauling and crushing.

Today, most mining companies are still mostly manually operated, however many are pursuing a full automation strategy without human intervention (aka Level 9 automation), where all manually operated equipment including diggers, ore haulers, crushers and trains will eventually be replaced with their autonomous counterparts.

Remote operations will further empower automation, enabling key personnel to monitor automated processes and operate machinery at a distance, using virtual telepresence.

“ Our best day in a manned operation is what we get every day in an autonomous operation.”

Making the transition to autonomous haulage

Autonomous haulage systems (AHS) play an increasingly crucial role in effective mine management as more and more operations transition from manned to unmanned fleets.

AHS technology has already delivered proven benefits in safety, productivity, durability and system flexibility across a range of mining environments. In 13 years of operation, Komatsu has recorded

zero system related accidents or injuries. And with no need to stop for shift changes or crib breaks, they increase productivity and production too.

AHS trucks consistently drive at optimum speed, while also providing more accurate component life prediction, reduced tire wear and higher fuel efficiency.



Photo: Komatsu

Private wireless, the technology of choice for mining automation

The digital transformation of mines requires mission-critical wireless connectivity. Over the last decade, point solutions, such as Wi-Fi, have been deployed. But they also have limited capabilities, as the figure shows.

4.9G/LTE mobile technology is now available for private wireless networks. This meets the requirements and sets the standard for even the most ambitious digital mining applications – including autonomous haulage.

Nokia industrial wireless solutions, based on LTE and now evolving to 5G, are able to support all mission- and business-critical applications on a single network. Typical applications include push-to-talk and push-to-video, high-definition video, low-latency edge computing for remote, automated and autonomous operations and support for low-power sensor networks, telemetry and IoT applications and analytics.

Wi-Fi	4.9G / LTE
 Capacity: ~30-100 active connections per access point.	 Capacity: up to 800 connections on a single small cell; tens of thousands on a macro antenna.
 Coverage: access point radius of ~50-100 meters; truck-mounted APs to cover the whole pit.	 Coverage: radius from 100 meters up to 30 km; 5-10 times less antennas needed.
 QoS: best effort; lack of prior prioritization.	 QoS: dependable quality of service management with prioritization.
 Performance: high peak rates; unstable performance/capacity.	 Performance: predictable data rates; 3-5 x9's "carrier grade" reliability.
 Mobility: loss of connection up to 15 secs on handover between APs.	 Mobility: up to 350 km/h
 Latency: fluctuating between 1 ms and 2 secs; reliability decreases with number of connections.	 Latency: between 8-20 ms; remains stable with increasing number of connections.
 Security: higher risk for hacker attacks and intrusion.	 Security: security by design
 Services: co-existence with private radio, no IoT support; no handover to public network.	 Services: one network for PTT/PTV, broadband, video streaming, IoT; same technology as public 4G.
 OpEx: frequent reconfigurations needed, up to 15 hrs/week.	 OpEx: 4 times less configuration, management and maintenance cost.

Komatsu AHS making the case for private LTE

Komatsu's FrontRunner AHS gives the company more than a single smart truck. Its intuitive autonomous system draws on rich data to seamlessly optimize haulage fleets, across the entire value chain.

A key component of any AHS deployment is mine-wide connectivity with seamless worksite mobility and enterprise-grade security. LTE technology is ideal, providing Komatsu with the standards-based features that today's proprietary point-to-multipoint networks simply aren't capable of delivering.

People's safety in the field is dependent on that network. As such, the quality of service mechanisms that are built into the network play a direct role in ensuring the delivery of critical messages such as 'stop'.

Predictable, consistent network performance is vital, providing miners with enterprise level visibility and central command control and helping to maximize safety, utilization and 24/7 productivity.

Even manned truck productivity increases with good connectivity, because the fleet can be better managed.

Nokia's private LTE solution has also become a key enabler on Komatsu's Industry 4.0 journey, allowing their mining division to meet customer demand by building a robust development network while also meeting key deployment timelines.

LTE made it possible to co-locate applications on a single network/modem too – simply not possible on Wi-Fi – and to run real-time data collection and analytics in parallel with mission critical traffic.

Komatsu has also diversified the types of data collected around reliability and service-awareness, driving the creation of better autonomous driving software and powered by better insights.

Mines worldwide are increasing safety, driving up productivity by more than 15% and reducing TCO by combining the robustness and durability of Komatsu trucks with

the power of FrontRunner AHS and Nokia's private wireless technology.

Connected trucks are by far safer than manually operated ones, because they can proactively communicate their position and intents to surrounding equipment or operators. Autonomous Haul Trucks (AHT) with a reliable network connection are also more productive.

A Komatsu internal study with Wi-Fi connected AHTs at three production sites revealed that communications

equipment problems – up to 5 or 6 errors per truck per hour – accounted for 15.13% of time lost during a 24-hour period, adding up to 13 minutes of lost time per AHT per day.

Transitioning to LTE at a production customer site reduced these kind of communication errors per truck operating hour by 84.6%. This resulted in a productivity increase of 8.5%, up to 250,000 tons per year, depending on shovel output rates.



Photo: Komatsu



Photo: Komatsu

Use case: Hang time reduction

Hang time is the amount of time that a shovel or a digging unit might hang with a full bucket waiting to dump that first bucket in the truck. On average, hang time consumes about 13 % of valuable shovel cycle time that you can't get back.

An ideal load cycle minimizes shovel hang time, optimizes the shovel swing angle and maximizes trucking capacity. But accomplishing this ideal load cycle is not an easy task, as the efficiency and safety of haul truck maneuvering at shovels, crushers, and dumps varies dramatically with operator skill.

With an AHS in place, a shovel can reach zero hang time as the truck navigates to the right spot point automatically, without the shovel needing to hang as a visual indicator.

At a rate of 18 loads per hour and 20 hours per day, automated operations have shown to add 547.5 extra hours of shovel capacity and a productivity increase of more than 2 million tons per year.

Coverage, capacity, latency

Compared to Wi-Fi, LTE usually has much higher allowed output power. This results in a longer range and a greater coverage. It also has lower frequency bands, allowing signals to travel further on the same amount of power. LTE licensed and coordinated frequencies also lead to less noise.

Reliability

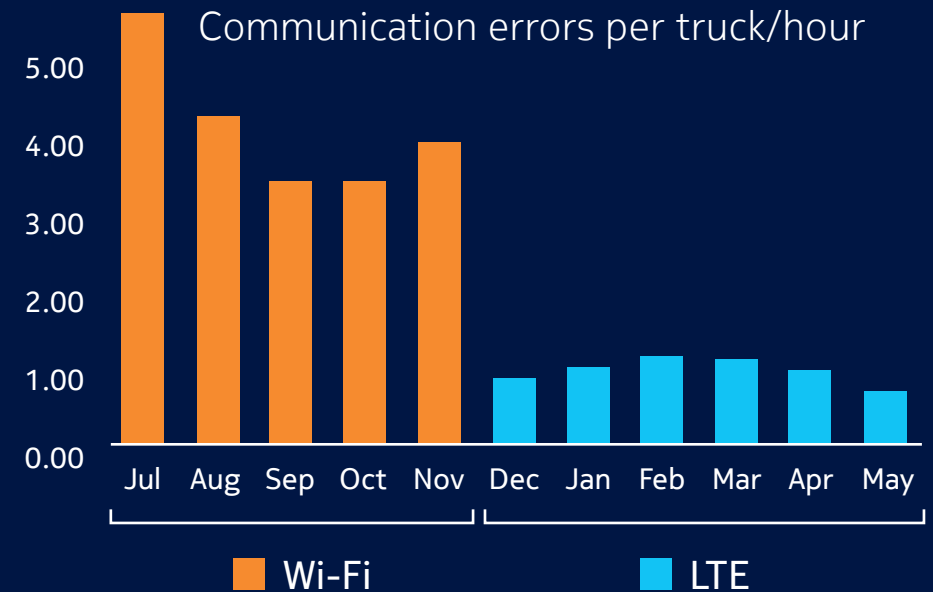
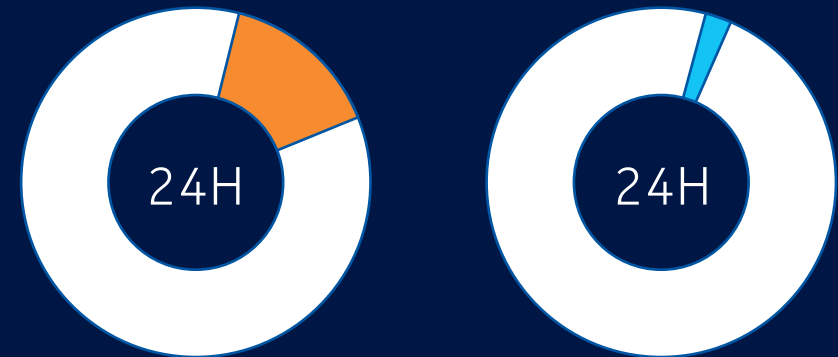
LTE's private, licensed, full duplex air interface is more reliable and message delivery is vastly better than on 802.11 Wi-Fi. It allows for the immediate notification of errored frames to the UE and scheduled re-broadcast. Fewer access points also mean less equipment to maintain, resulting in a better maintenance focus per equipment, less work for field teams and greater uptime.

When Komatsu transitioned their proving grounds from Wi-Fi to LTE, the packet loss observed on any given day on Wi-Fi was about 4%. A single commissioning drive test on LTE logged a mere 4 lost packets out of 50,000. That's an exponentially better performance.

Quality of Service (QoS)

LTE's full duplex transmission and its built-in robust QoS mechanisms are together leading to a dynamic shift in network capabilities. This connection sharing leads to better outcomes for mission critical applications compared to sharing the same workload on traditional 802.11 Wi-Fi systems. On LTE, multiple clients can transmit simultaneously within the same frequency space. This allows for fine grained traffic control, ensuring that UE's with high priority get more network resources and that critical traffic is delivered on-time.

Time lost per truck/hour caused by communication equipment problems



Source: Komatsu, data from 3 AHS production sites

Komatsu and Nokia, from now to next

Partnerships are key for innovation and constantly advancing technology, quality and business performance in any sector – but in mining, it's mission-critical.

Mine automation isn't the future; it's happening right now, and the Komatsu AHS has been helping surface mining operations around the world improve margins since its first commercial deployment in 2008.

Komatsu was the world's first company to offer autonomous haulage on LTE. The collaboration of Komatsu and Nokia at the Arizona proving grounds has been a key enabler for meeting Komatsu AHS development and deployment timelines.

While private LTE has helped to make these gains a reality, the next technology leap, 5G, will deliver even higher speeds, ultra-reliable low-latency communication and native support for massive machine communication and IoT applications.

At the same time, advanced data analytics and machine learning will provide new means to analyze complex terrain for navigation, predict behaviors and actions and identify the anomalies that create safety hazards.

Nokia and Komatsu are committed to continuing our joint journey to take mining automation to the next level – developing new network-enabled solutions that will create ever-safer, more productive and efficient mines.

“ LTE's increased network reliability allowed us to focus resources on application development and customer value instead of always having to ask: 'is this caused by the network?'”

David Haukeness,
AHS Product Manager, Komatsu

“ We are keeping a close watch on the emerging 5G technology. It has the potential to enable massive instrumentation and analytics and open up as-yet undiscovered avenues for product improvement and downstream innovation.”

William Nassauer,
AHS Product Strategy manager, Komatsu



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As a B2B technology innovation leader, we are pioneering the future where networks meet cloud to realize the full potential of digital in every industry.

Through networks that sense, think and act, we work with our customers and partners to create the digital services and applications of the future.

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