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Autonomous mobile machines in mines and 5G enabled safety principles

Abstract: There is a strong need to have autonomous or semi-autonomous mobile machines in mines. They enable increased productivity and improved safety, as workers do not need to be continuously present in the most dangerous areas of the mine. Several strategies are needed to minimize risks related to collisions. Fences or virtual fences can provide a good safety level, but they are laborious to configure in a continuously changing environment. Tracking of all persons and vehicles, combined with on-board sensors for object detection, could be able to provide dynamic safety without compromising productivity. However, capability in all environmental conditions is not yet adequate. Traffic rules are good additional means to improve safety, but not sufficient for autonomous systems. Almost always, good communication is required between machines, operators and infrastructure. Lost integrity or availability of communication can have impacts on safety and production. 5G introduces new possibilities to build reliable and quick networks.

Keywords: Functional safety, mining operations, autonomous mobile machines

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1 Introduction

This paper focuses on new safety principles enabled by 5G, pointing out risks, mitigation strategies, functional safety principles and communication safety principles. A comprehensive study will be available in VTT Technology publication “Autonomous mobile machines in mines using 5G enabled operational safety principles” [1]. This paper introduces selected ideas of safety functions, which can be applied with autonomous mobile machines in mines. The focus is on cases where 5G communication is applied.

The focus of this article is on collision avoidance. Autonomous mobile machines are typically large, and all collisions cause considerable damages. If a person is involved with the collision the severity is considered fatal in the risk assessment. Also a collision of two driverless vehicles can have hazardous consequences in mines.

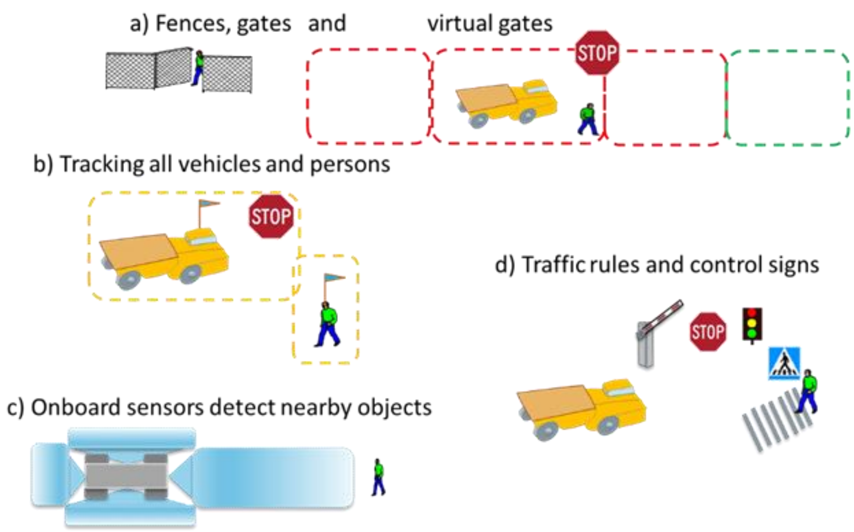

Figure 1 Strategies to mitigate autonomous mobile machines collisions.

One aspect related to communication is that safety means are concentrated on safety layer, which is above actual communication protocols [2]. In many cases, messages need to be sent via several stations using wireless or wired communication. The logical communication between safety layers of two nodes is considered black channel, which may have different safety capabilities, which can be difficult to evaluate in a dynamic environment.

The strategies to mitigate risks are here divided into 4 groups presented in Figure 1: a) fences, gates and virtual gates/fences, b) tracking of persons and vehicles, c) on-board sensors to get an overview of objects in the vicinity, d) traffic rules. To make a safe mobile machinery system in mines often several mitigating strategies are needed. Communication between machines, operators, fleet control and infrastructure, is necessary in all of the strategies. Sensors onboard the mobile machine (case c) at the figure) could operate for a while without communication, but there must be means to stop all machines and for emergency stop communication is required. [1]

2 Methods

The research was done in NGMining project and the ideas of safety strategies have emerged in discussions, presentations and workshops in the project. There have been several case studies in the project related to communication (mainly 5G).

3 Results and conclusions

The safety and availability of communication are important factors in mines, especially in future digitalized mining, where physical mining process are increasingly automated and executed by teleoperated or fully autonomous mining machines. In highly digitalized and automated mining operations the availability of communication had key role in ensuring continuity of production at the mining site. Safety issues are often related to integrity of messages and there are requirements for integrity, for example, safety integrity level 2 (SIL). Availability requirements can be related to safety, but typically loss of communication leads to a safe state i.e., stopping. The time to endure communication delays needs to be defined in risk assessment. For example, in bridge cranes the acceptable time delay is typically 500 ms and similar value can be applied in mobile machines too. Although availability issues do not usually cause safety issues, a long-lasting communication loss can cause huge financial losses due to lost production.

The communication systems in mines are changing continuously as new tunnels are built. Therefore, some parts of the communication can be difficult to be defined as white channel according to IEC 61508-2. Safety measures can be done also in sender and receiver in their safety layer. This means that the communication is made in black channel, which includes 5G. Since 5G is inside the black channel, its properties are not considered in safety assessment of the communication channel. However, reliable communication affects the share of messages that the safety layer accepts and furthermore it has an effect on dependability in general.

A relatively new category of risks in mine communication are related to cybersecurity. The mines are usually deep underground and therefore general cybersecurity threats/attacks are rare. However, it is wise to consider vulnerabilities of communication and control systems to avoid cybersecurity issues.

Strategies and principles to mitigate collision risks need to be chosen. Most of the strategies require safety functions, which are related to control systems and communication. Safety functions are related to functional safety, including safety integrity levels (SIL) and performance levels (PL). Furthermore, control systems are related also to cybersecurity and dependability in general.

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4 Bibliography

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