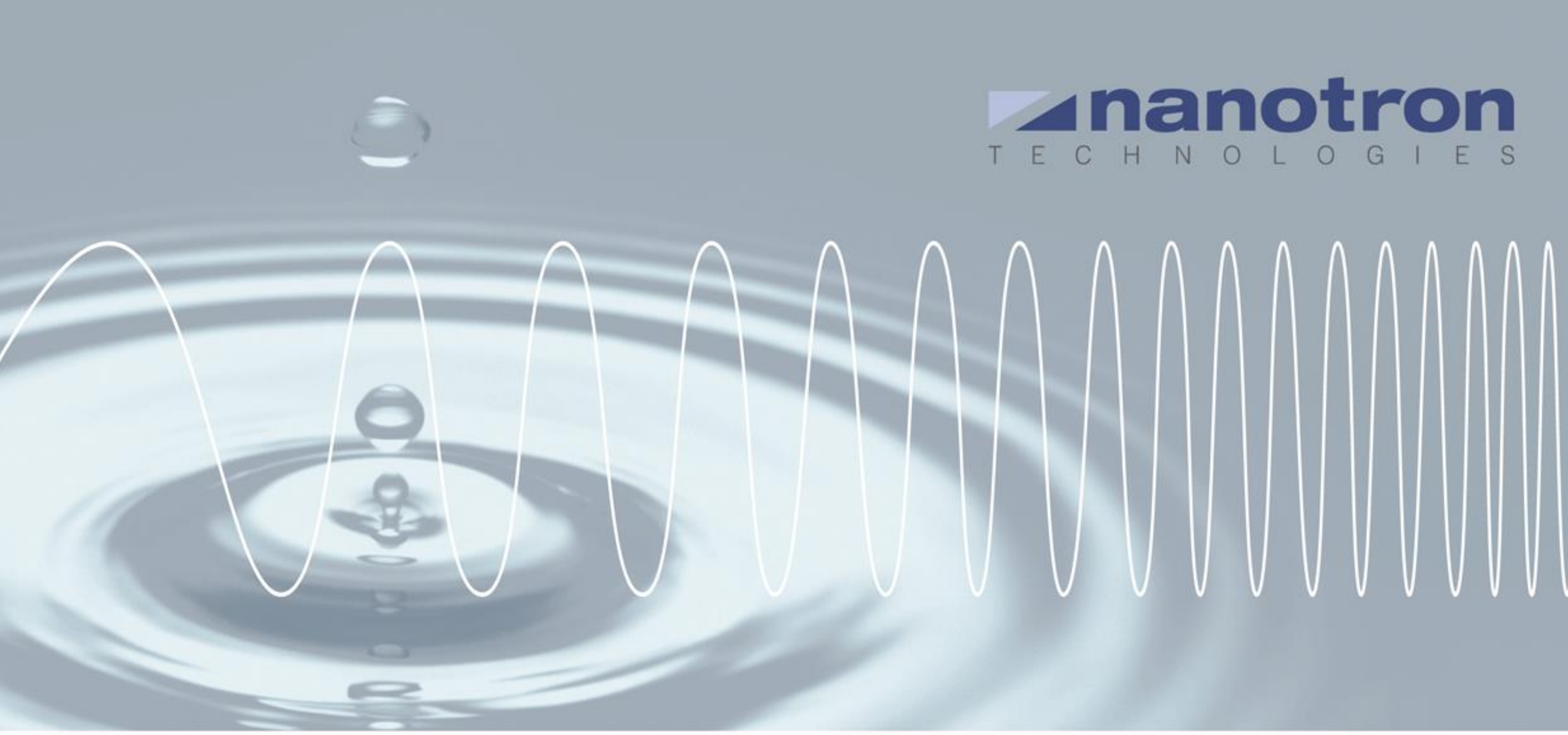

AN0503 Using *swarm* bee LE for Collision Avoidance Systems (CAS)

1.3

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Contents

1. Outline

Nanotron has released it's newly evolved generation of *swarm* products, including a range of modules called *swarm* bee LE (LE = Low Energy). These products feature an updated high-level API, on board sensors with 3D acceleration, temperature, and Vcc monitoring. They mark an important evolution for rapid development of customized embedded collision avoidance applications (CAS). The *swarm* bee LE is a low-energy module that can be easily integrated into both portable tags as well as vehicles to provide CAS solutions tailored to specific market and customer requirements.

The scope of this Applications Note is to outline the main considerations in the architecture of a CAS application to provide a basis for implementation of the *swarm* bee LE module into CAS system.

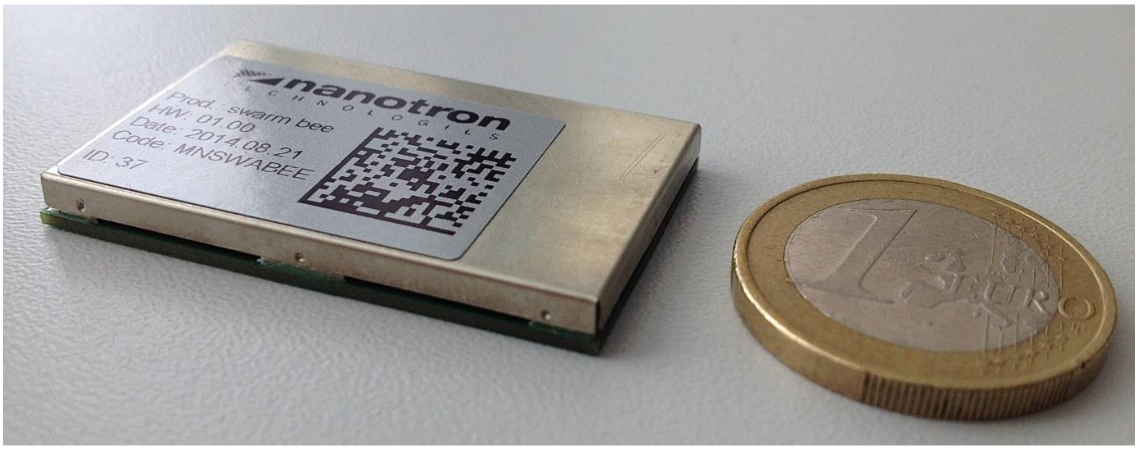

Figure 1: *swarm* bee LE radio module

2. Fixed and Collaborative Location Methods

2.1. Collaborative Location

Collaborative location uses relative positions to provide location-awareness. Radio nodes determine the distance to neighbors by exchanging packets and measuring their round-trip time of flight (TOF) at the speed of light. This method is called ranging. Radios are autonomous, location infrastructure is not required. Figure 2 shows an example for collaborative loaction. All nodes for personnel and vehicles are implemented using swarm bee LE modules.

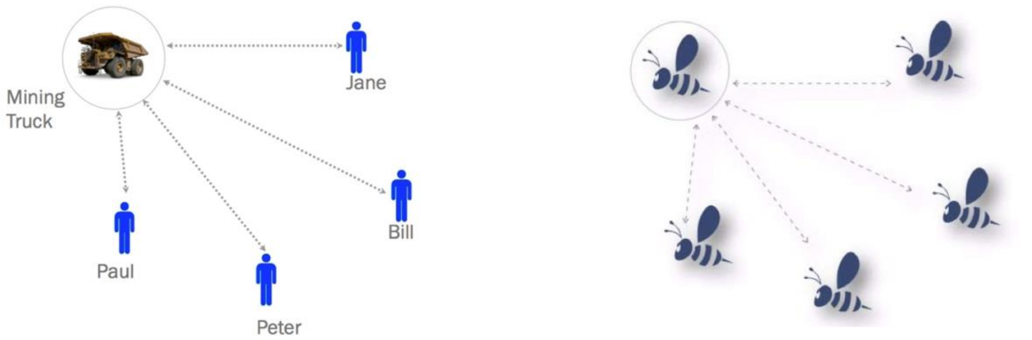

Figure 2 Collaborative Location

2.2. Fixed Location

This uses fixed reference points or 'Anchors' to provide location awareness. Anchors are connected to a standard network, and a central computer or server tracks the positions of the tags. Because this system is based on time difference of arrival (TDOA), only one data packet sent from the tag is required to get a position fix in 1D, 2D or 3D. The need to only transmit a single packet reduces power consumption of the tag significantly. Less packets in the air per position fix allow for a larger number of objects to be tracked. *swarm* bee LE module appears as a tag on the Fixed Location System. It is a modular product with a compact footprint suitable for integration into a customized tag.

Figure 3 shows a simple nanotron fixed location infrastructure (Anchors). All *swarm* bee LE modules appear as tags on this system. On the map anchors appear in green while *swarm* radios appear as red dots.

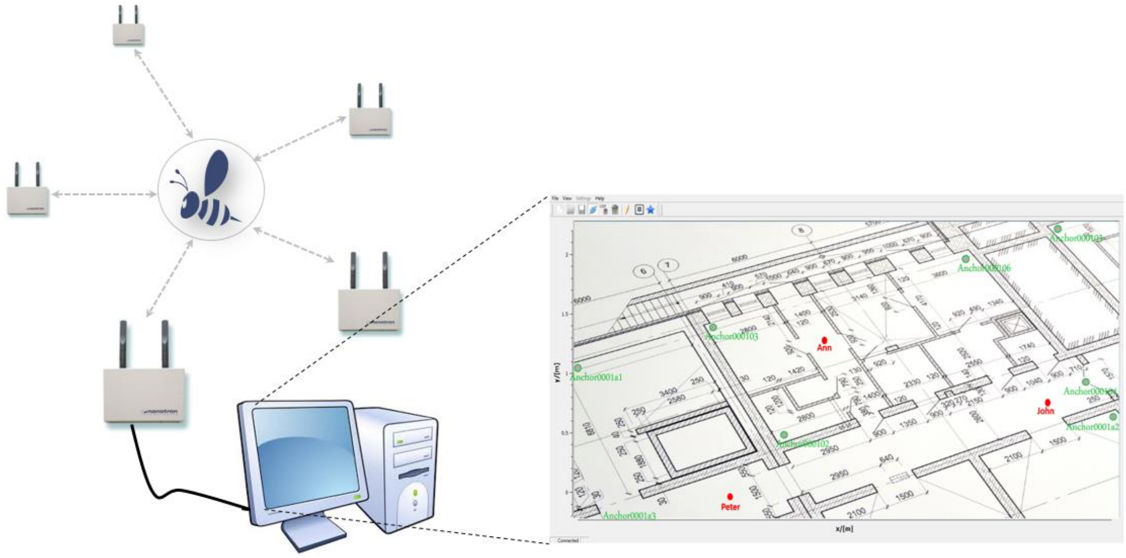

Figure 3 Fixed Location Infrastructure

3. *swarm* embedded Platform Technology

The new *swarm* bee LE radios provide embedded autonomous 2.4 GHz Chirp Spread Spectrum wireless nodes. These are the basic *swarm* building blocks for the system (Figure 1). They are able to broadcast and exchange messages while monitoring distances to other individuals in the *swarm* which are the key capabilities that allow for coordinated *swarm* behavior. When in range of anchors they can also communicate messages to and from the fixed location server (nanoLES).

Each individual in a wireless *swarm* consists of a *swarm* bee LE radio that is capable of working autonomously or connected to a host. In this second case the host controls the *swarm* through its application programing interface (API). There are several categories of API commands (Figure 4). The RaTo <node ID> command for instance returns the distance to another node.

Various power-down modes are also supported in the API to enable extended battery life in portable tags.

Ranging
RATO RangeTo
BRAR Broadcast RAnging Results
SROB Selects Ranging Operation Blinks
ERRN Enables Ranging Result Notification

Set-Up
SNID Sets the Node ID
GNID Get Node ID of the node connected
SSET Save SETtings; saves all settings
STXP Sets transmission (TX) Power
SPSA Set Power Saving Active
SSYC Set the PHY SYnCword
BLDR BootLoaDeR, switch to bootloader
GPBL Get Privacy BlackList.
GRWL Get Ranging White List

Data Communication
EDAN Enables DAta Notification
SDAT Sends DATa to node ID
GDAT Gets received DATa
BDAT Broadcasts DATa

New in API 3!!!
- Multiple blink rates supported
- New Power Mode 3 added
- GPIO Wake up function in any power mode
- Number of syncwords extended
- Better Support for Antenna Diversity and coexistence
- Selectable UART speed

Figure 4 Subset overview of nanotron's *swarm* text API commands.

In the latest version of the API Binary commands are also available

3.1. Characteristics of a CAS system

The quality of location-awareness depends on two basic criteria: Accuracy and latency. Accuracy is the difference between measured and true distance. Usually it could be characterized by a fixed off-set and the spread of results as shown in Figure 5. In this case the accuracy achieved was around 30cm radius with 90% of the results within this. This is typical for an outdoor application where there is low mutipath and a reasonable distance. Latency specifies the time required to obtain a ranging result. It has a strong impact on the real-time character of the application. Short messages and quick responses help to minimize latency thus maximizing throughput. A *swarm* bee LE radio requires 1.94 milliseconds of air time for executing a SDS-TWR cycle, nanotron's patented Symmetrical Double-Sided Two Way Ranging. To broadcast its ID it only requires 350 microseconds.

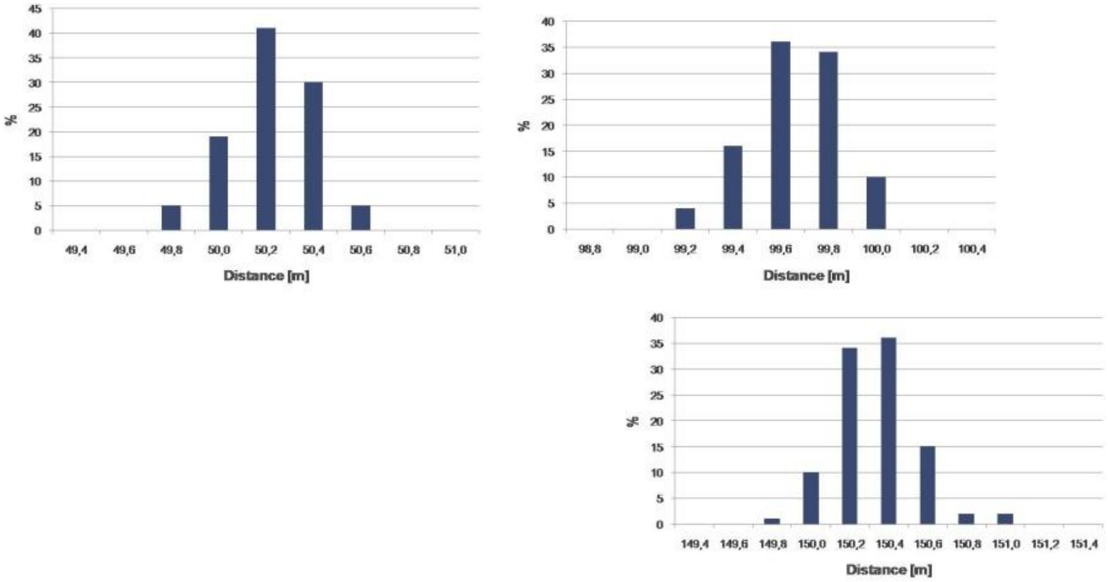

Figure 5 Ranging Accuracy - Ranging Accuracy is characterized by offset and spread. The actual distances are 50, 100, and 150m respectively

The maximum obtainable range of the *swarm* radios determines how far apart individuals in the *swarm* are still able to interact. Maximum range is highly dependent on the application environment. Under ideal line-of-sight conditions range can exceed 1200 meters; however, in reality it often can be reduced due to obstacles, reflections, interference from other radio signals, antenna miss-alignment etc.

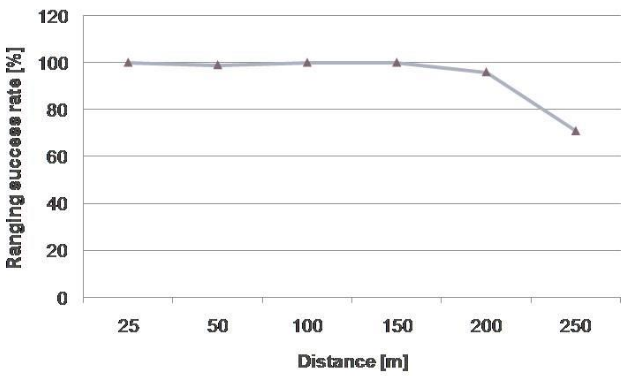

Figure 6 Range measurement between a pedestrian and a car

This figure shows a real world example with one *swarm* radio inside a car and the other carried by a person. Range could be extended by placing the antenna on the outside of a car or by having the antenna installed on a hard-hat instead on a belt.

3.2. CAS in Mining Applications

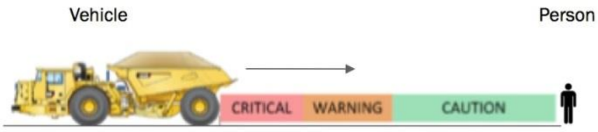

Figure 7 CAS virtual safety zones

There is a need for automatic collision avoidance in mining. In order to prevent accidents a reliable alarm is required whenever vehicles come too close to people, assets or other vehicles. The *swarm* Bee LE location technology is well-suited for implementing these types of CAS applications.

A simplified set-up with vehicles, assets and people – a total of three node types – is used to illustrate the essential outline of the application. In the worst case scenario two objects move towards each other at maximum speed (Figure 8). The system needs to react faster than the time necessary for the objects to traverse the respective safety zone for the shortest path collision course. In our example the shortest time is 2.2 seconds; therefore latency of the CAS system must be kept short and the whole group of nodes needs to complete the full location awareness cycle faster than in 2.2 seconds. For reliable operation one might decide to accelerate the sequence in order to execute it several times within this interval.

Vehicle to …	Vehicle	Asset	Person	
Safety Zone	3B 60 m	1.5B 30 m	2B 40 m	in multiples of braking distance B = 20 m
Maximum Speed	50 km/h	-	10 km/h	
Safe Time	2.2 sec	2.2 sec	2.4 sec	

Figure 8 Safety zones and resulting safe time to respond

3.3. Designing a typical Host Controller Program for *swarm* bee LE

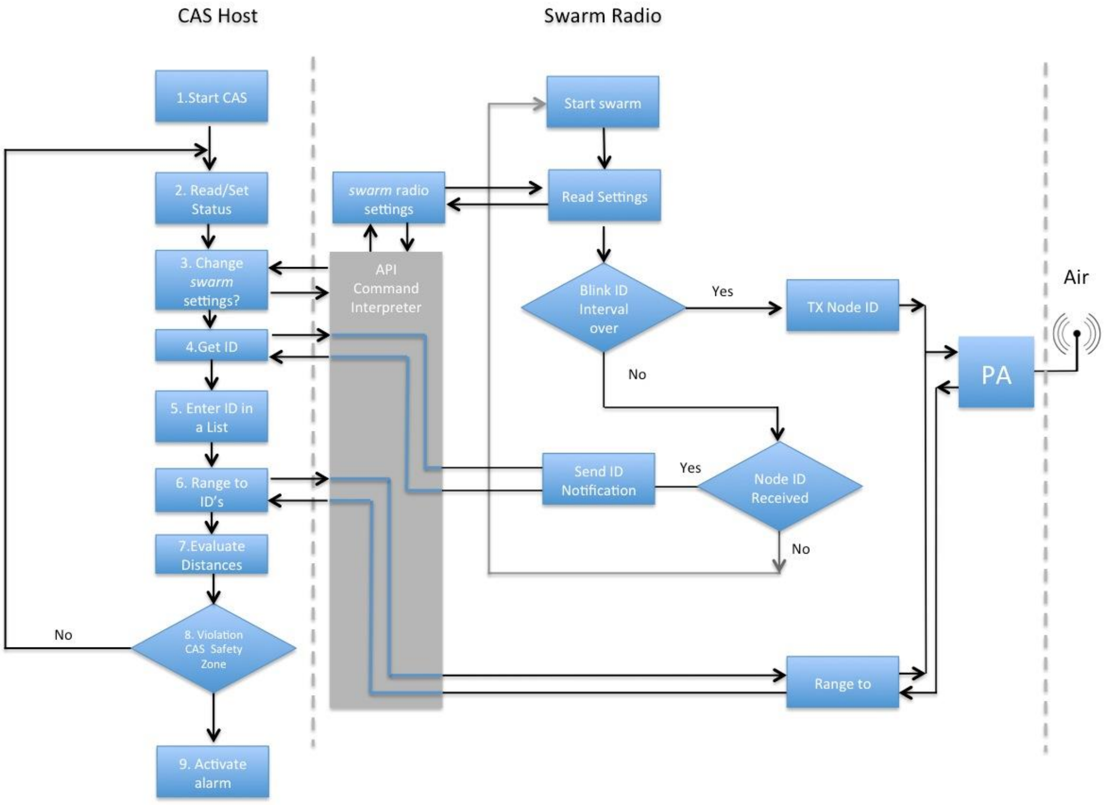

Figure 9: Option 1

After step (3) two options are possible according to the configuratio the user prefers:
Option 1:
(4) The *swarm* radio connected to the host has the automatic range request option deactivated. It listens for blinks from other devices and when it receives one it sends the ID of the blink's originator as a *nodeId notification* to the CAS host. The CAS host can then make a list (5) with all the IDs received.
(6) CAS host checks its own list and sends the *swarm* bee a 'range to' (`RATO <NodeID>`) command. *swarm* will perform a ranging opretation with the requested node and will send the result back to the host.

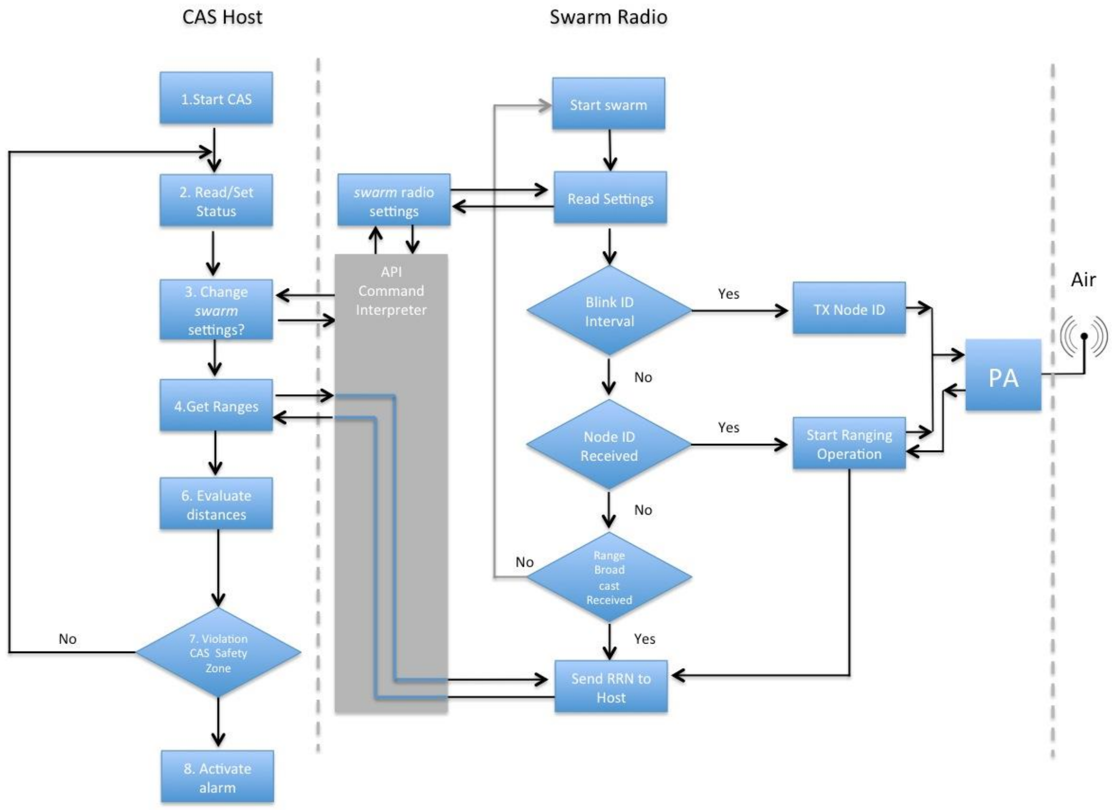

Figure 10: Option 2

Option 2:
(4) The other *swarm*s in the network have ranging result broadcast active. The *swarm* radio makes itself visible by broadcasting its own ID in a blink. Option `SBID=1` and `SBIV=1000` for example sets the broadcast of a blink every second.
(5) When the *swarm* receives a blink it starts a ranging operation with the node that generated it. With the data gathered it estimated the range, broadcast it over the air and sends it to the CAS host as a *range result notification* (RRN). The other *swarm* in the neigbourhood will do the same; thus when they receive any blink they perform a ranging operation and broadcast the result. The *swarm* connected to the CAS host will receive all broadcasted ranges and pass them to the host as a RRN.

Evaluate distances (6): In a third step the CAS application needs to decide whether any of the measured distances violates a safety zone requirement and needs to take action if it does. It may involve a simple audio alarm on approach or exercising the brakes of a truck to prevent an imminent collision.

As part of designing the CAS application it is now possible to estimate the time required to execute one location awareness cycle and trigger an alarm if required. The sequence in our example takes less than 30 milliseconds; hence the time constraint mentioned above can be easily met.

All *swarm* radios share the same air interface. The CAS application works in an entirely asynchronous fashion and packet collisions may occur. Several location awareness cycles instead of just one increase the probability of a successful sequence. At the same time traffic through the air interface must not exceed channel capacity. Broadcasting the node ID together with a full ranging cycle takes about 2.2 milliseconds of the air time. This is just 0.1% of the 2.2 second cycle time for the CAS application. As a rule of thumb no more than 17% of the available airtime should be used as a good trade-off between success rate and throughput. This is important when scaling the application by adding more *swarm* radios.

4. Discussion

In real *swarm* bee LE applications safety zones can be designed to be dynamically adjusted to the actual speed of the moving object and the last measured distance on a potential collision course. This way the total number of alarms can be minimized and the number of *swam* radios that can be used in the system before channel saturation occurs, can be maximized.

5. Conclusions

Nanotron's *swarm* bee LE embedded platform is well-suited to rapidly build CAS applications. *Swarm* radios are location aware since they are able to measure distances amongst themselves and exchange the results. Range, ranging accuracy, latency and throughput are important design criteria for location applications based on the *swarm* bee LE embedded platform.

Document History

Date	Version	Version
2014-09-30	1.0	Application note on how to see the use *swarm* for a CAS
2015-04-09	1.2	Updated Figure 4 with API 2.03 commands
2016-04-25	1.3	Updated Figure 4 with API 3.0 commands

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About Nanotron Technologies GmbH

Today nanotron's *embedded location platform* delivers location-awareness for safety and productivity solutions across industrial and consumer markets. The platform consists of chips, modules and software that enable precise real-time positioning and concurrent wireless communication. The ubiquitous proliferation of interoperable location platforms is creating the location-aware Internet of Things.

Further Information

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