HOLISTIC SMART PRODUCTS FOR NUCLEAR SECURITY
Radiation detectors of the future will have on-board signal processing and be IP-addressable

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Abstract

Radiation detectors with fully integrated digital readout and Power-over-Ethernet (PoE) connectors enable a whole set of new applications and services. In this paper, neutron and gamma detectors will be presented which are read out by low-power Silicon Photomultipliers (SiPMs) that allow for long autonomy from mains power supply when deployed in the field. This is especially needed in applications where detectors are mounted on unmanned vehicles or drones, or in applications where networked devices are mounted to cars or relocatable detection systems.
The Power-over-Ethernet connector allows direct addressability of each detector by its IP address when several detectors are networked. This information flows into smart software solutions which take advantage of this feature to adjust machine learning algorithms. If GPS is also provided then a simple mapping of an area is obtained within a short timeframe.
Such rapid situational awareness is especially useful in case of a CBRNe incident or for intelligence services to get a clear picture of a site or environment. The information can also be provided to smart city networks.
The presented software ensures that limited training of operators is needed, which has an impact on the cost of an exercise.
In addition, as PoE based radiation detectors are designed to be networked, all information can flow into an on-site or remote central alarm station where appropriate measures are taken to react in case of an alarm or anomaly.
The SiPM readout allows the presented gamma detector to be thinner then 2 cm and widely scalable in width. This feature is interesting for applications where limited space is available, for example for airports where the detectors can be integrated into existing layouts and walls to monitor passengers or luggage.
In addition to the many advantages fully digital radiation detectors provide during operations, PoE also allows simple plug and play maintenance concepts which will be presented in this paper.

1. THE PROBLEM WITH LEGACY SYSTEMS

After the tragic events of 9/11, many countries rushed to deploy radiation detection systems. Today, more than a decade later, the organizations that have been operating such systems have refined their requirements to reflect what they desire to procure in the future compared to the kit currently in place.

Legacy detection systems tend to be “closed” systems, meaning, the vendor who provides the systems also provides the spares and the software, including future updates. This fact has a number of implications that deteriorate performance and drive up cost over the total lifetime of such systems.

1.1. High procurement and maintenance costs

For vendors it is attractive to sell “closed” systems, as it exposes vendors to very little if any competition in the provision of spares, software updates or specific maintenance. As attractive as this is for vendors, the cost hidden cost is enormous.

1.2. Inhibited introduction of new technical breakthroughs

The closed architecture of legacy systems effectively prevents new technologies from being introduced to upgrade their performance. For example, the US Department of Homeland Security spent several millions involving national labs in the development of machine learning algorithms to improve the performance of radiation portal monitors. Regardless of the success and potential of such developments, getting them deployed to fielded systems has proven to be an almost insurmountable obstacle, given that legacy system providers have little incentives to allow sufficient access to their “closed” systems.

1.3. Obsolescence problems

Similar to the example discussed above, closed systems have obsolescence problems. For example, many operators would like to move away from using ^{3}He based neutron detectors as these become obsolete. Yet retrofitting systems with modern replacement technologies has proven to be a costly compatibility problem.

2. TECHNICAL ADVANCES TOWARDS SOLUTION

The recent years have brought technical advances that hold promise to disrupt the current state of the art of system design. This section will discuss how detectors are transitioning from being dumb, high voltage discharge devices with custom interfaces to being smart, plug-and-play, semiconductor-based systems with on-board intelligence. Such smart detectors are the building blocks of open architecture systems that overcome the challenges reviewed in the previous section.

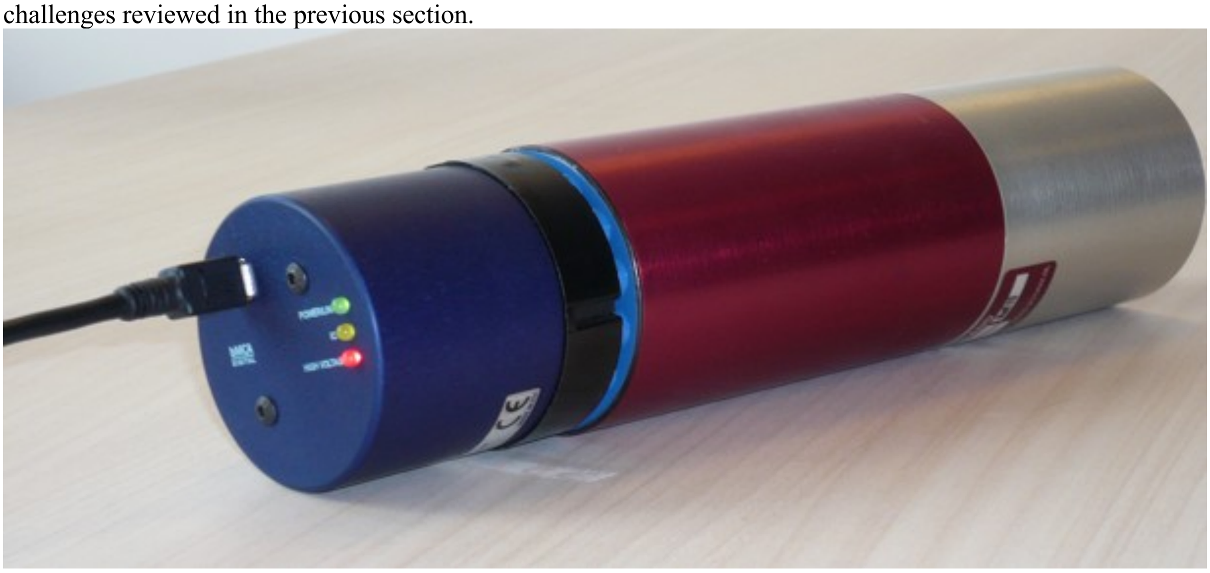

FIG. 1. A Power-over Ethernet gamma detector [1]. This gamma detector has one single electrical interface in the form of an Ethernet cable, which provides power, control, and signal output in a single connection. The detector has on-board signal processing and is IP-addressable, making detector replacement a plug-and-play effort.

2.4. Power-over-Ethernet

Power-over-Ethernet (PoE) has emerged as a universal technology to interconnect nodes to a network. Not surprisingly, Power-over-Ethernet has found its way into radiation detectors too. Today, several vendors offer gamma detectors or neutron detectors with Ethernet connections; Fig. 1 shows a PoE gamma detector. This allows the sensors to be connected to the rest of a detection system in the same manner as all other ancillary sensors (cameras, occupancy sensors, license plate readers, etc.). In fact, the "rest of the detection system" becomes Commercially Available Off the Shelf components, such as computers and routers, massively reducing the cost of a system, see Figs. 2 and 3.

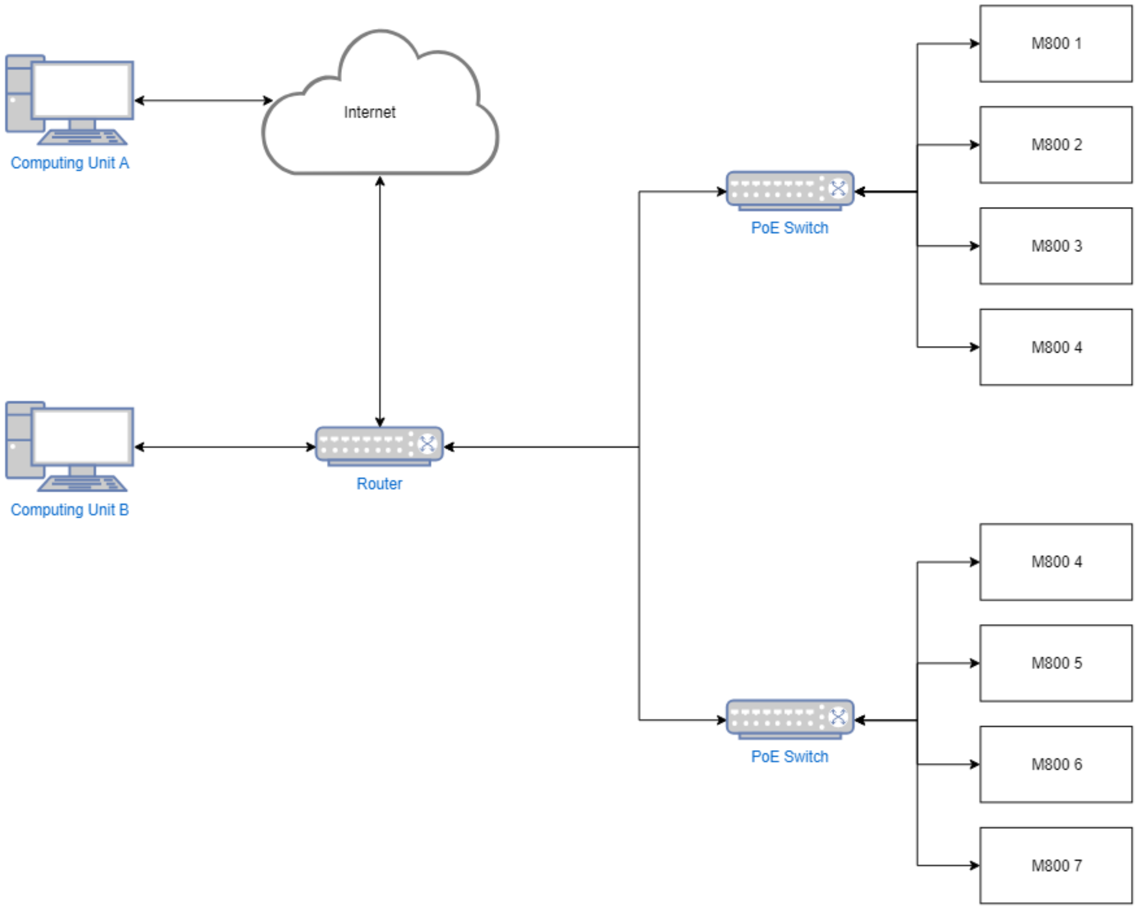

FIG. 2. Smart detectors networked to a system. By having IP-addressable, Power-over-Ethernet radiation detectors (labelled as M800 x in this graphic), a radiation detection system can be built using commercial off the shelf computers, routers, and ancillary sensors, dramatically reducing the system cost. Maintenance costs are also dramatically reduced, as faulty components can be replaced in a plug-and-play manner.

2.5. On-board intelligence

Power-over-Ethernet (PoE) detectors typically integrate on-board signal processing directly within the sensor. For example, a smart gamma detector may have an integrated multi-channel analyser. Not only is it favourable from a signal-to-noise point of view to process the raw data as close as possible to the sensor, but the overall system architecture is simplified. Each sensor – regardless of whether radiation detector or ancillary sensor such as a camera – has its own IP address. If a sensor is replaced, the new sensor's calibration can automatically be updated based on the IP address. This applies for integrated detection systems, such as radiation portal monitors, and distributed detection systems, such as environmental monitoring networks, see Figs. 2 and 3.

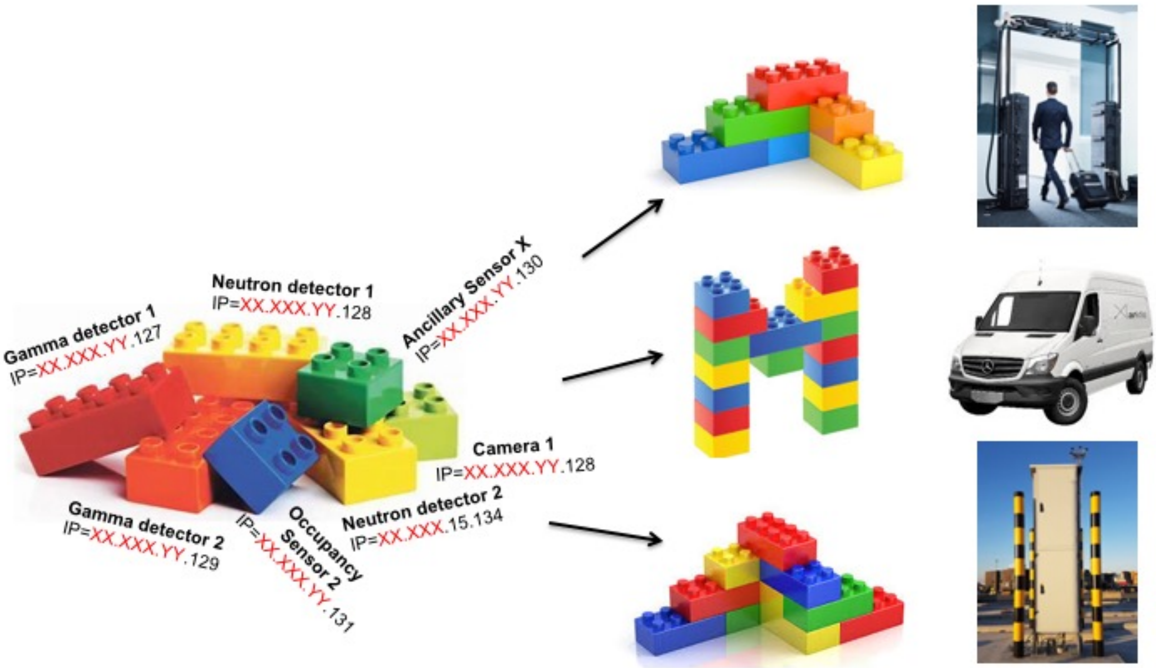

FIG. 3. By using smart sensors, radiation detection systems of very different form factors end up taking a very modular form, variations on a theme of a common architecture.

2.6. SiPMs replacing high voltage discharge devices

Still today, the majority of radiation detectors employ some form of high voltage discharge technology. For example, most large scintillation detectors have Photomultiplier Tubes (PMTs), that involve manual labor in their manufacturing. For neutron detection, even today many detectors are proportional tubes, involving a high voltage anode wire strong down the length of a tube filled with gas. These high-voltage discharge technologies have been around for about a century and are slowly getting replaced by Silicon Photomultiplier (SiPM) solutions. SiPM based detectors don't require high voltage, take up a fraction of the space, do not require manual labour in their production and, in line with the theme of this paper, lend themselves to application in smart detectors in networked applications. Today, SiPM technology is successfully being deployed in large area gamma detectors as well as in large are neutron detectors, see Figs. 4 and 5.

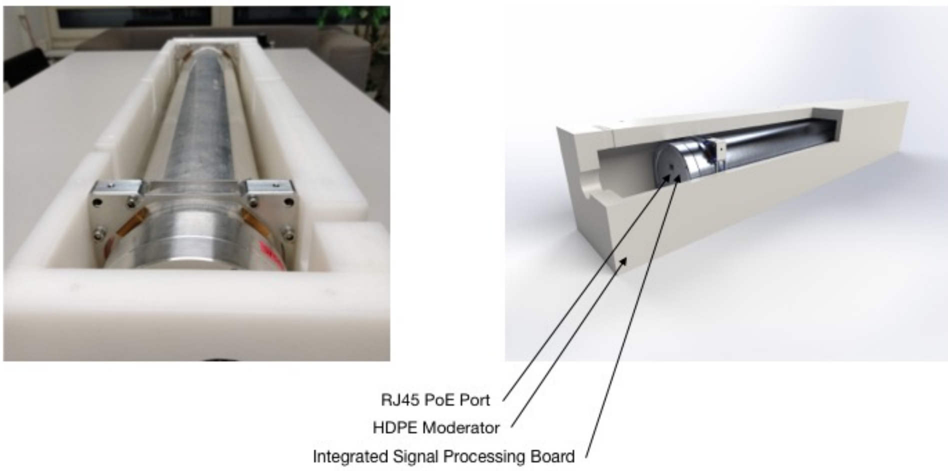

FIG. 4. A SiPM based, Power-over-Ethernet smart neutron detector in its moderator. Such devices have achieved superior performance and lower cost compared to proportional counters.

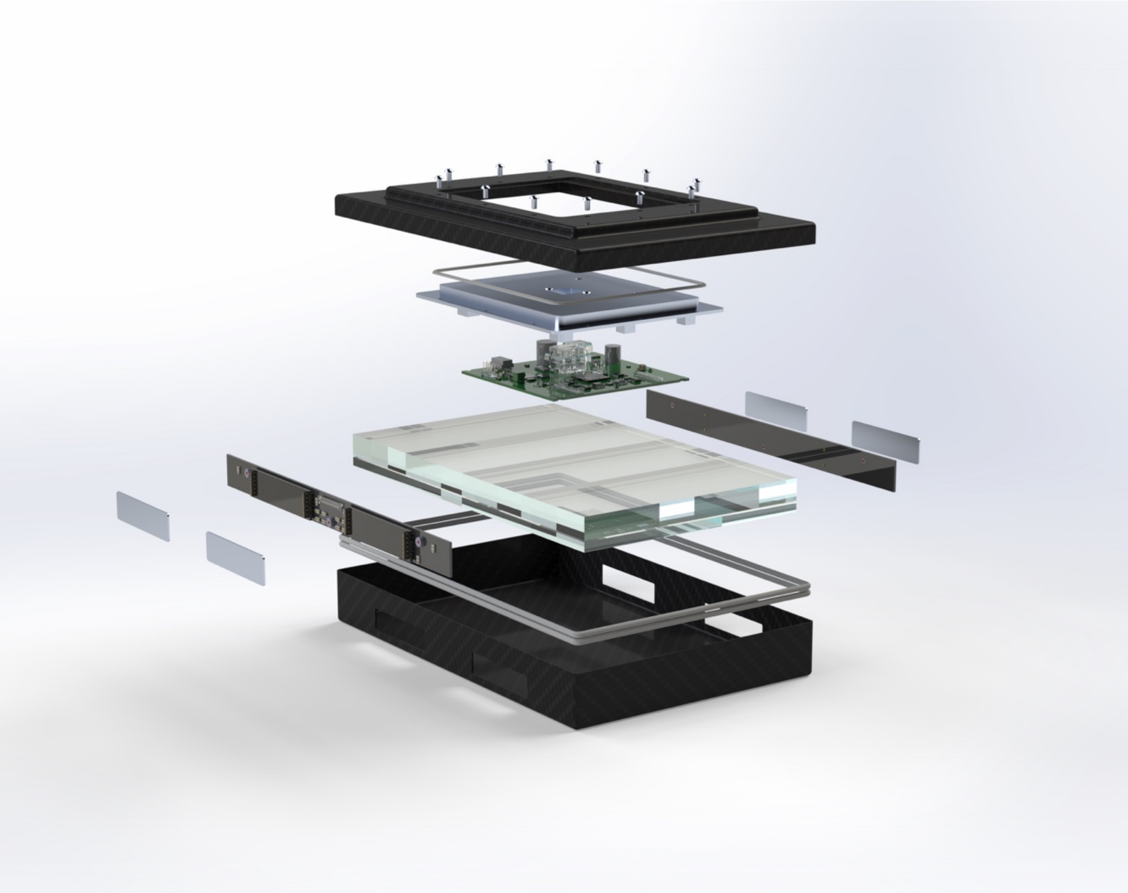

FIG. 5. Explosion view of a SiPM based, Power-over-Ethernet smart Flat Panel Gamma FPG detector. Such devices have achieved superior performance to bulky PMT based devices, and are close to achieving cost parity.

3. LEADING ROLE OF US GOVERNMENT

The US Department of Homeland Security has taken a leading role in realizing the potential offered by smart sensors and used this to inform future procurements. In particular, it has launched a program named RAPTER, previously called ROSA (RPM Open Systems Architecture). In the ROSA Request for Information (RFI), DHS publishes its suggestions regarding interfaces and communications between the components of an open architecture detection system of smart sensors [2].

4. CONCLUSION

In summary, the following hypotheses can be formulated. Next generation detection systems will have open architectures. They will be built up of IP addressable, smart radiation sensors, with Power-over-Ethernet connections. This will radically reduce the through-life cost of such systems.

REFERENCES

[1] Brightspec bMCA technology, http://www.brightspec.be/brightspec/?q=node/12
[2] US Department of Homeland Security, CWMD, 600-ROSA-122790v0.12