MESSAGE BROKER TECHNOLOGY FOR FLEXIBLE SIGNALLING CONTROL

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SUMMARY

There is a trend for railway infrastructure managers to invest in large regional control centres, which can deliver significant reductions in operating cost and improved efficiency of traffic management. A key requirement for the signalling control systems in the new control centres is the ability to interface with electronic and relay interlockings in existing smaller control centres and signalboxes, passenger and staff information systems, and national IT systems used for timetable and maintenance planning. The systems must also provide a flexible and future proof capability to interface with new traffic management tools, ERTMS/ETCS radio block centres, and driver advisory systems.

Similar requirements in distributed information systems more generally have led to the concept of "service oriented architecture". DeltaRail has adopted this approach in the development of IECC Scalable, the next-generation successor to IECC which is the most widely installed signalling control system in the UK, with over 50 workstations deployed on the busiest and most complex parts of the network.

The core of the system is a commercial off the shelf "message broker" which links the software components. This is compatible with Ethernet based communications technology, allowing remote deployment of any part of the functionality. For example, this allows interlocking interfaces to be located adjacent to the re-controlled interlockings in the superseded control centres and signalboxes, and signaller workstations to be networked between the new control centres.

The paper will describe the technology choices that have been made and their application in a safety related environment that needs to be compliant with CENELEC standards for signalling systems. There will also be some practical examples of how the new system can be deployed to accelerate the pace of control centre migration and deliver additional early benefits.

1 INTRODUCTION

Traditional requirements for signalling control systems focus on the ability to interface safely with electronic and relay interlockings in order to control the flow of traffic through the "span of control," maintaining operation close to a published timetable. The complexity of the systems range from the deployment of electronic VDU based systems to replace traditional panels to those, including the IECC installations operating on many of the UK's most complex sections of route, that provide automatic route setting. This has led to the creation of dedicated systems that serve the needs of the signalling control centre extremely well. They have therefore tended to be developed as engineering solutions in isolation both from the needs of the "customers" for Signalling Control within their own business environment, and from the innovations that are a routine feature of the IT marketplace.

There are various changes in the environment that are creating the need for more flexible and integrated solutions. Some of the drivers for this include: the need to interface with wider route planning applications to enable the improved use of resources across larger control areas; the emergence of new control technologies such as ERTMS and ETCS; the availability of driver advisory systems to aid traffic flow and improve energy consumption; automatic train operation; the increasing demands and expectations of the travelling public to be better informed about end to end journey choices; and, the changing framework within which many infrastructure operators will be operating, such as the regulatory and structural impacts on the UK Railway from the recent government paper on obtaining greater efficiency and investment returns headed by Sir Roy McNulty.

Responding to these changes, DeltaRail[1] has refreshed its offering to provide a new generation of Signalling Control product, IECC Scalable, which at the time of writing is in operation on the Great Western Mainline and on

[1] DeltaRail is a UK based company providing Signalling Control solutions and project delivery services.

a Modular Signalling scheme in East Anglia. The earlier versions of IECC, named for convenience as IECC Classic, have a strong presence on the UK railway. They deliver VDU based control with advanced features such as approved automatic route setting and have established the standards in many areas of operation and communication in this environment.

In this paper, we describe the architecture implemented on IECC Scalable and explain how this opens up a connected future for Signalling Control, sitting at the heart of the railway operation, acquiring data and publishing information to an 'internet of things[2]' that can be consumed in a variety of ways by a knowledge hungry business and its customers. This will drive improvement through knowledge based decision making and communications across the environment it operates within. We also describe some of the challenges this presents and give an example of the benefits the first steps down this road will deliver.

1.1 An Overview of the Architecture

IECC Scalable uses a service-based architecture to provide its capability. Service based architectures have existed in information systems for several years now, although they have rarely featured in railway control applications, largely due to the closed nature of many of those systems, their isolation from broader enterprise systems and their origins being in earlier generations of design. Increasingly, as indicated earlier, there is the need to view the control function as part of the operation of the rail system, not solely for the safe and efficient control of the infrastructure. In developing IECC Scalable, the service based architecture has enabled:

- Selective upgrade or replacement of key functions;
- The retention of core capability, such as the proven automatic route setting functions;
- Re-use of capability and information;
- An information-centric model, capable of extension to include further information without the need to modify core functions that are cleanly separated from the source.

[2] According to Gartner, "The Internet of Things is a concept that describes how the Internet is being used to link smart devices, conventional consumer items, and physical assets so that these new endpoints can create and receive a data stream. The trend is developing fast. Nearly every product could become part of it. A plant can tweet that it needs water; manufacturing equipment can monitor its status and schedule maintenance; and consumer appliances and cars are connected; it's no longer science fiction — all examples exist today."

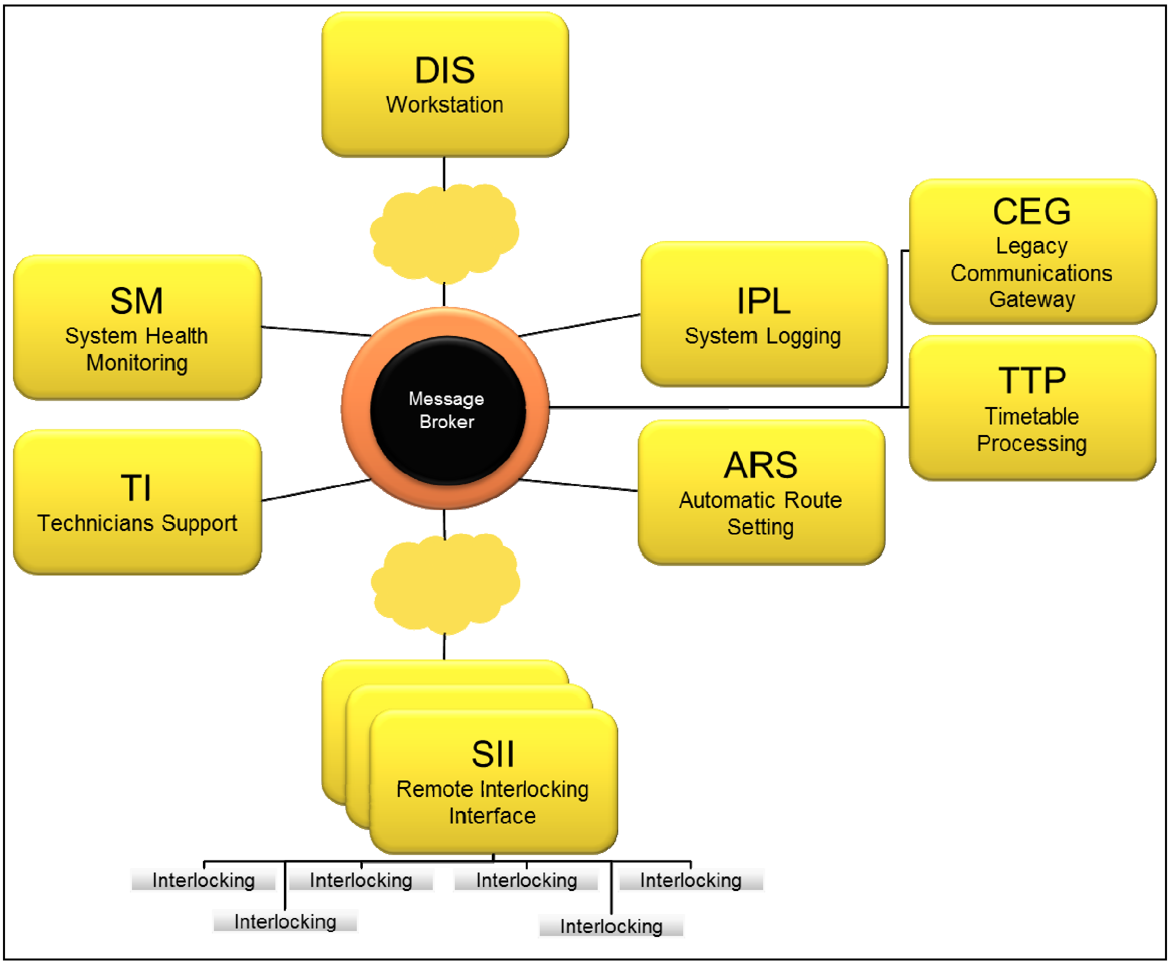

Figure 1 An Overview of the IECC Scalable Architecture

An overview of the architecture of the system is given in Figure 1. The key modules providing the system's capability are:

- Workstations (known as DIS) are capable of being deployed over an open network remote from the main IECC Scalable cabinets, providing significant flexibility in the use of buildings and skilled human resources.
- The system monitoring (SM) and technicians' interface (TI) have been designed such that the health monitoring will be co-located with the critical functions, while the user interface for the health status and support functions can be provided over any suitable network. This then supports the deployment either at remote locations or within managed data centres where physical access is typically restricted.
- The Automatic Route Setting (ARS) and its supporting Timetable Processor (TTP) are co-located on the core system and, with over a billion routes set already, bring forward this proven capability to a new generation of control applications.
- The IPL provides system logging both for diagnosis and in the event of an operational incident occurring on the network requiring post-event causal analysis.
- A legacy communications gateway (CEG) is provided for the variety of systems deployed on the network that require dedicated point to point communications, often including serial connectivity.
- An interface for all SSI compatible interlockings (the SII module), plus adaptors for other types of interlockings. This interface can be deployed at any point on the network supported by Ethernet based comms. Other interfaces are also provided for devices capable of using the MODBUS protocols.

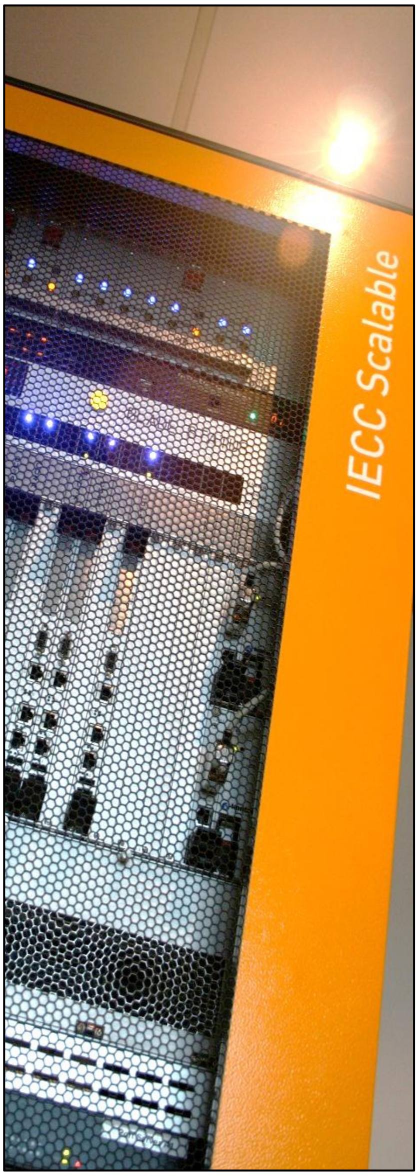

Figure 2 The IECC Scalable Cabinet

1.1.1 Messaging

IECC Scalable has been developed around a message based information architecture. Key principles have included the use of COTS and open, public communication methodologies. The main technologies adopted to achieve this are Message Brokers, standard Protocols and Ethernet communications. This has provided a number of advantages in the development of the product and importantly, in designing an IT based route to future maintenance.

Message Brokers come in many flavours in the commercial and open source software markets. Their key function is the assured delivery of content over wide area communications network. They typically operate on a publish-subscribe model, whereby a sub-system or remote monitor has a new piece of data that is of interest to any number of subscribing applications whose purpose will be to create information or value from that data. Messages are published to and obtained from any number of topics[3] that are registered with the broker. This model is more efficient than polling based models where there is a large number of remote publishing and subscribing devices or applications. It is event driven so messages only issue when triggered by an external event (such as the change in state of the measured system), so are efficient with network traffic. The approach does not suffer from the timing lags that can occur when polling numerous devices in a cyclical manner.

For IECC Scalable, the IBM Really Small Message Broker technology has been deployed. This uses a truly open messaging protocol known as MQTT[4]. This technology forms part of the IBM Websphere family of products that has been deployed in a variety of transaction based applications. Example deployments include the large scale financial systems that support the world's banks, processing several billion pounds worth of transactions every day; smart metering systems that are being trialled in various towns to improve the on-demand use of national grid resources; remote monitoring of pace makers in patients, avoiding the need for long distance travel for routine appointments in countries such as Australia and Canada; and the remote monitoring of road traffic networks to facilitate the control and improved movement of vehicles and people in smarter cities. All these examples are environments where critical data is being transmitted over open networks.

While the reliability, performance and availability of communications networks is continually improving, most commercial or general purpose networks will not provide the secure transport or operate at the more demanding levels of resilience and assurance. The commercially available message brokers have proven themselves in numerous challenging environments and have been designed and tested against the numerous "edge cases" which can cause failures in network communications.

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[3] In a topic-based system, messages are published to "topics" or named logical channels. Subscribers in a topic-based system will receive all messages published to the topics to which they subscribe, and all subscribers to a topic will receive the same messages. The publisher is responsible for defining the classes of messages to which subscribers can subscribe. Nested structures are used to define the topic, so a device for monitoring energy consumption and temperature might post on <My Town>/<My Street>/<My House>/<Power Consumption> and <My Town>/<My Street>/<My House>/<Temperature>, allowing interested listeners to subscribe to all events in the town or a specific to a single house.

[4] MQ Telemetry Transport: According to mqtt.org, "MQTT is a machine-to-machine (M2M)/"Internet of Things" connectivity protocol. It was designed as an extremely lightweight publish/subscribe messaging transport. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium."

In typical deployments, assured delivery by the Broker is more critical than the speed of delivery. In developing Safety Related applications for near real time use, the design needs also to deliver the system's performance requirements. The Message Broker alone cannot be relied on to deliver the adequate performance, as this is impacted by the configuration of the system's physical resources and the reliance on open and closed (dedicated) networks. In practice, even over relatively large control areas, the typical volume of transactions occurring does not stretch the capability of this technology in a well-designed system running on modern hardware. However, not all significant issues relating to performance and security will be fully excluded by the network operator or the bought in technology. The CENELEC standards, with which the Signalling Control systems comply, set out a number of threats and defences that must be handled when communicating between (sub)systems. In IECC Scalable, this has been handled explicitly by providing an Adaptor to sit between each publisher and subscriber which has in built strategies to deal with corrupted and malicious messages using a variety of techniques including selective digital signing of messages based on criticality and unique sequence based identification. This Adaptor is available for re-use and extension to provide connectivity to other information sources as they become available (ERTMS train control or GPS train position are potential sources of relevance). The source can publish via the Adaptor and applications can subscribe through it, exploiting the capabilities of a proven, approved message adaptor that already handles threats and defences recognised by the CENELEC standards.

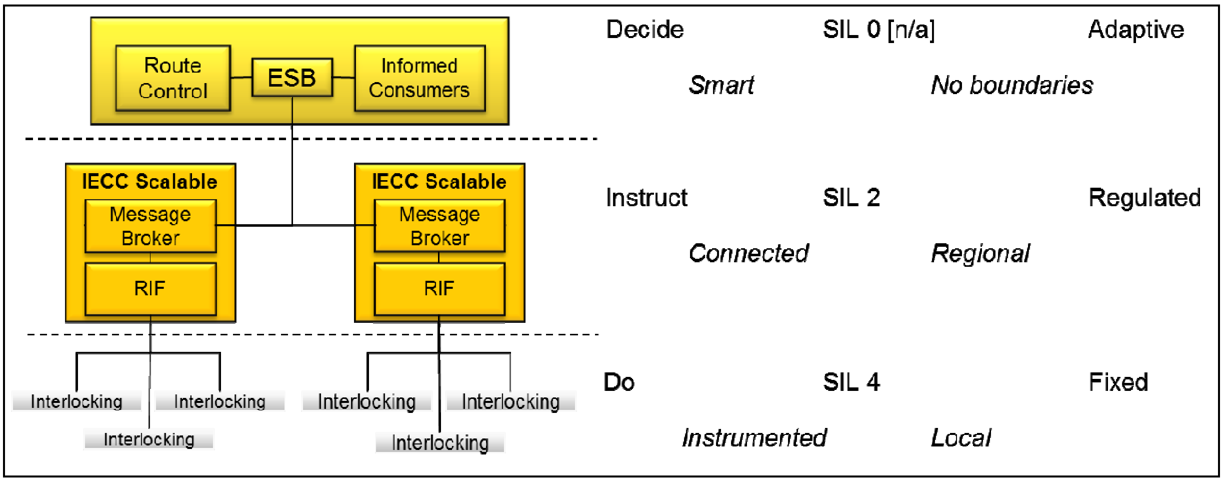

Figure 3 Connecting Controls and Separating Functions

1.2 Benefits of the Architecture

In Information Management sectors, much is made of the "ecosystem" in which a technology exists as a key determinant for its longevity and the rationale to buy. Vital signs of the ecosystem include the strength and trajectory of the supporting development and supplier base making available resources, governance and components. In marrying the IECC Scalable product to the WebSphere message broker technology provided by IBM, it has moved into a significant and thriving ecosystem that supports numerous critical business and government applications.

The architecture adopted by IECC Scalable, enables a number of benefits to be realised in the Signalling Control environments. These include:

- Flexible deployment across Ethernet based networks. This enables the consolidation of resources, both environmental (buildings) and people, based on function and competence rather than geography. This also aids resilience with a duplicated "cabinet" capable of being located in two physically separate, managed environments.
- First application costs are reduced through the use of, and reuse of, standard components both COTS and bespoke. Validation becomes simpler with communications to external systems managed in a consistent and secure manner through the system, exploiting commercially available technologies proven in a range of mission critical business and government applications.
- Whole life costs are reduced through the use of standardised components which can be maintained, replaced and upgraded using approaches developed in the information sectors.

- Enterprise integration – the Signalling Control application no longer needs to reside at the edge of the business architecture, it can behave as a an integrated publisher of data on the status of the network and as a subscriber to information or instructions from specified and trusted sources.

A further range of applications and benefits can be opened up when considering multiple instances of the product deployed across a route or region. Key to opening up these benefits is structuring a functional and information based architecture that combines the appetites of the business and consumers for knowledge based decisions in a rapidly evolving environment with the need for resilient and safe control on the track. To support this, a layered architecture is demanded, the key principles of which are shown in Figure 3. The major structural principles relate to the separation of function according to both the safety criticality and purpose, ranging from acting (on data) to instructing (on information) to decisions (based on knowledge). Information and data flowing between layers must move through secure and assured gateways to protect the safety related functions and provide reliable trusted sources to any relevant subscribers. Such approaches are already well established in many industrial process based control systems. With such principles established and embedded through the architecture and its associated governance models, a wide range of commercially available technologies are made accessible to accelerate the deployment of applications.

The Websphere family of products, as an example of a heavyweight suite of middleware systems provided by IBM, provides analytical capability, optimisation, workflow and dissemination. This enables the Signalling Control capability to be connected to the wider environment within which it operates, simplifying and clarifying the route that data often takes once extracted from the control environment. Disconnected from its source, data on the state of the railway may well have undergone transformations and aggregations before reaching applications that are intended to interpret the message. In the architecture presented here, the data acquired and created by the Signalling Control system (including train movements, infrastructure status, timetables and route setting decisions) can be published and used to inform a wide range of subscribers, from route planners to support staff to the travelling public. By making data available to the "Internet of Things", a new set of uses and applications will emerge.

1.3 Challenges with the new architecture

This model does throw down challenges to the traditional Signalling project environment, which should be considered by the industry in evaluating the benefits this architecture can deliver:

- The control of the data and the purpose of any applications that exploit that data pass will need some form of regulation if they are to be reliable and relevant to both suppliers and consumers. Applications are created and survive according to the value they provide, less so a pre-determined need, which changes the role of the regulator from specifier to moderator. The regulator will have to cede control of the end functions however if the benefits from having a competitive application supply market are to be realised. The assurance and approvals functions will need to focus appropriately on the specific risks and threats presented by new Applications, but will stifle innovation if this extends to all functional provision.
- Protection of the safety critical and related layers becomes even more important in this model. Consumers and businesses will only acquire the services offered if the data accessed through the "Internet of Things" can be trusted. There may be differential levels of data quality provided, with real time, assured delivery commanding premium prices, but should the content prove to be unreliable, subscriptions will fail to reach levels to support the service. There will be a role for data stewardship, and whether that comes from an existing industry body or emerges from the supply base remains to be seen.
- The take up of IT technology and principles will require an increased frequency of upgrades and refreshes to take place. Properly planned, this will deliver the benefits outlined in this paper and ensure that Signalling Control avoids the legacy technology traps and stays connected the rest of the business and its customers. The approvals process will need to adapt to ensure the high standards of safe operation are maintained, while technology refreshes become more cost effective.

1.4 Early Benefits: Consolidation of Control Centres

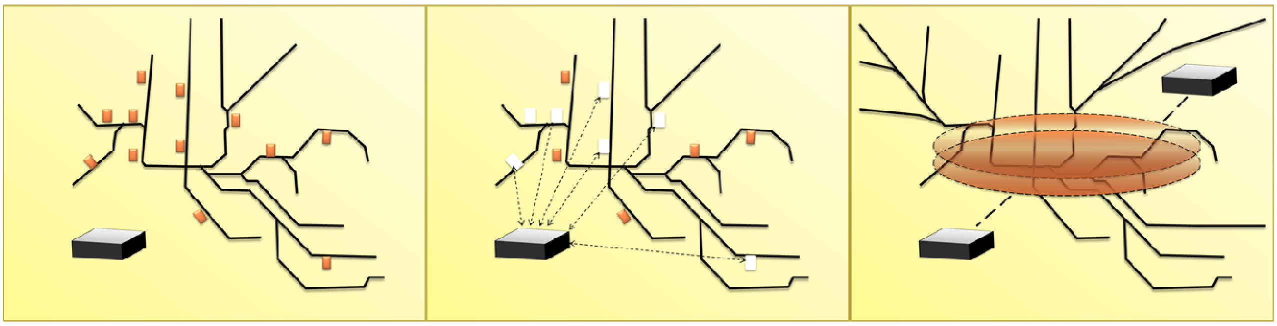

Figure 4 The Evolution of Control

The early benefits will come from two main aspects of the architecture: the capability to operate reliably and securely over Ethernet networks and the use of COTS technologies to deliver the hardware components. These two principles enable control to be run remotely and to consolidate the competency into control and data management centres. Figure 4 shows a simple schematic whereby remote signalling locations can be integrated into a centralised control structure, both by connecting the interlockings via the network and by co-locating the control function. Studies have been done both by Network Rail and others in the UK and have identified significant operational savings from this approach. Most of these studies have not yet gone as far as looking at the benefits of consolidating the operation of the server based equipment into dedicated data centres, potentially with split site operation for improved resilience.

Other benefits will then be derived by moving to a Management by Exception approach, supported by the technological developments discussed in this paper. The provision of this, whereby human supervision and intervention is only required when events on the ground fall outside of “normal operating parameters”, is supported by the use of message broker technologies and a move towards an “Internet of Things”. In the first, these brokers can easily be configured or have listening devices attached such that specific events or messages will trigger a pre-determined response – this could be as simple as a piece of equipment in the field or the data centre failing and triggering a request for an engineer to attend site or it could be watching for a specific event on the operational railway to prompt a response. The “Internet of Things” approach, coupled with the technologies for storing and analysing large volumes of operational data, will allow us to take this even further, with the capability to explore patterns in the data to look for similar events and review the actions taken previously to generate a successful outcome. In the event that there is no match, the management by exception procedures are invoked and the human skills come to the fore to fill the gaps in the system’s knowledge.

2 Conclusion

DeltaRail’s IECC Scalable provides a new generation of Signalling Control technology and offers the prospect of connecting this function to the wider business and consumer environment. It introduces Messaging Based communication both to issue control instructions but also to publish data out to new set of interested parties. It is now installed on the UK Railway.

This technology opens up a set of new benefits, both for the reliability and maintenance of the current technology, but more importantly for its extended future, through the use of an extensible service based architecture, open communications protocols and COTS based hardware. Looking beyond the Signalling Control discipline, the technology opens up a connected future, communicating with a far broader set of interested parties, destined to supply a number of applications and functions that have not currently even been considered.

The introduction of the architecture and technology does present challenges that need to be addressed by the industry if it is to take full advantage and avoid the repeated build-up of a technology debt that fails to move with the some of the major forces shaping the future of IT, such as the so-called Internet of Things. The encouragement for this approach is driven by the early benefits and on-going opportunities generated by these technology changes, such as the consolidation of control centres and the creation of further business and consumer applications.