AUTO ID PARADIGM SHIFTS FROM INTERNET OF THINGS TO THE UNIQUE IDENTIFICATION OF INDIVIDUAL DECISIONS IN SYSTEM OF SYSTEMS

Return on investment from radio frequency based tools of identification may increase with the diffusion of ultrawideband (UWB) and software-defined radio (SDR) as RFID readers. But the improvement of decision support demands the unique identification of information between system of systems to benefit from systems interoperability.

Nature's gift of the radio spectrum has been subjected by humans in government and industry to dissection and control, which has resulted in a globally fractured state of communication when using such frequencies. Redundant investments are necessary to move between "restricted" frequencies and the process has turned into a sham, with spectrum auctions being pioneered by several affluent nations for commercial purposes. Regulating the use of the radio spectrum has distinct advantages (defence, emergency, medicine) but the current commercial quagmire may overshadow the benefits.

During WWII, the discovery of RADAR unleashed the potential to use radio frequencies to identify objects. Almost half a century later, in 1987, Norway pioneered the first public use of radio frequency identification (RFID) in the form of RFID tags attached to automobiles that drove through toll collection points fitted with readers. The event triggered automated toll collection through a pre-agreed financial transaction. The RFID tag operated at a fixed frequency and the frequency used was (and is) irrelevant to the function of the static ID system. But, globalization has stimulated the movement of objects across diverse geographies. It is now imperative that we focus special attention on determining the "state of supply and demand" of goods. Calls for the global visibility of goods movement require automatic identification of the vast number (trillions) of objects moving around the globe. This necessity may be answered in part by harnessing the Internet to catalyse the rebirth of the use of RFID. Thus, Internet-based object identification was reborn at the hands of the Auto ID Center at MIT in 1999.

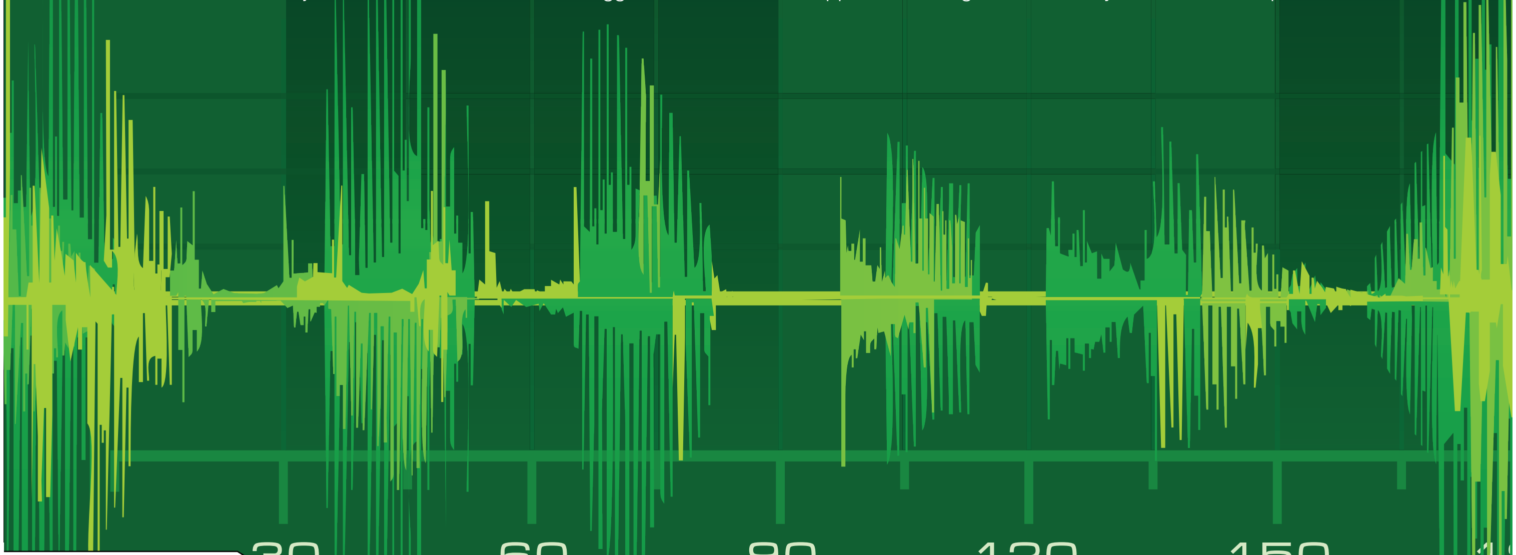
Opportunity: Potential to Eliminate Frequency Heterogeneity

The surge in the popularity of RFID ignored the limiting fact that most RFID tags operate at a fixed frequency and readers must also operate at the same fixed frequencies. Add to this mix the different spectrum usage specific to geographies — plus preferences for standards for data capture such as EPC (electronic product code) — and what emerges is an interoperability nightmare from a multitude of tags, readers, investment in multiple infrastructures and the conflicting complexity of multiple "standards" in a plethora of proprietary systems.

The problems with automatic identification should not suggest that it has lost its appeal. Auto ID and the concomitant location of objects are important data elements, whose value is growing exponentially in business supply chains, and are even more critical for the security of global trade — in multinational logistics operations when goods are transported between Asia and Europe on the Trans-Siberian Railroad, for example. In such systems, fixed frequency RFID tools may be a hindrance to operations and are liable to create gaps in (data) transparency owing to a lack of systems interoperability. This article highlights technologies that may eliminate frequency heterogeneity for some applications. However, this is not a panacea that calls for discontinuing the use of fixed frequency standards.

Frequency Agnostic Technologies: Ultrawideband (UWB) and Software Defined Radio (SDR)

In use since 1962, UWB is essentially RFID but it can communicate over a broad (hence, ultrawide) spectrum (band) rather than the fixed ranges that are common in typical RFID.[1] The physics of transmission is different and enables UWB to use short (picosecond) bursts of frequency across the broad spectrum (making it difficult to decode). This is a frequency agnostic tag that is currently used in several operations



as an active tag (battery) but holds the potential to be transformed into a passive format.

Invented in 1991, SDR is essentially a radio that can operate (receive and transmit) over a broad spectrum (think, car radio).[2] Hence, it can interrogate tags and receive signals from UWB tags. The incoming frequency is selected using the software embedded in these devices (hence, software defined radio), thus it is immune to frequency heterogeneity and functions in a manner that is frequency agnostic. The combination of frequency agnostic UWB tags and SDR readers may increase the diffusion of auto ID tools and enhance systemic implementation, globally.

Standards are Not a Standard Solution

Based on the current thinking that track and trace technologies must identify objects, it is necessary to capture the ID of objects in some alphanumeric format. Thus, current tools are drowning in a multiplicity of so-called standards. Problems encountered because of globalization result from the unlimited movement of objects (inanimate and animate things such as humans) in domains wherein the standards are not useful, practiced, accepted, adopted, implemented or enforced. Often, systems cannot communicate because of a lack of interoperability. Thus, we have an embarrassment of riches regarding data, but exist in a state of abject poverty concerning information, owing to a lack of interoperability in this systems age. The latter has, erroneously, promoted even more calls for standards … and even larger consortiums are being formed to muscle in global adoption (acceptance). The success of this approach is open to question, judging by the failure of Wal*Mart-esque efforts to usher in the global visibility that auto ID was touted to deliver.

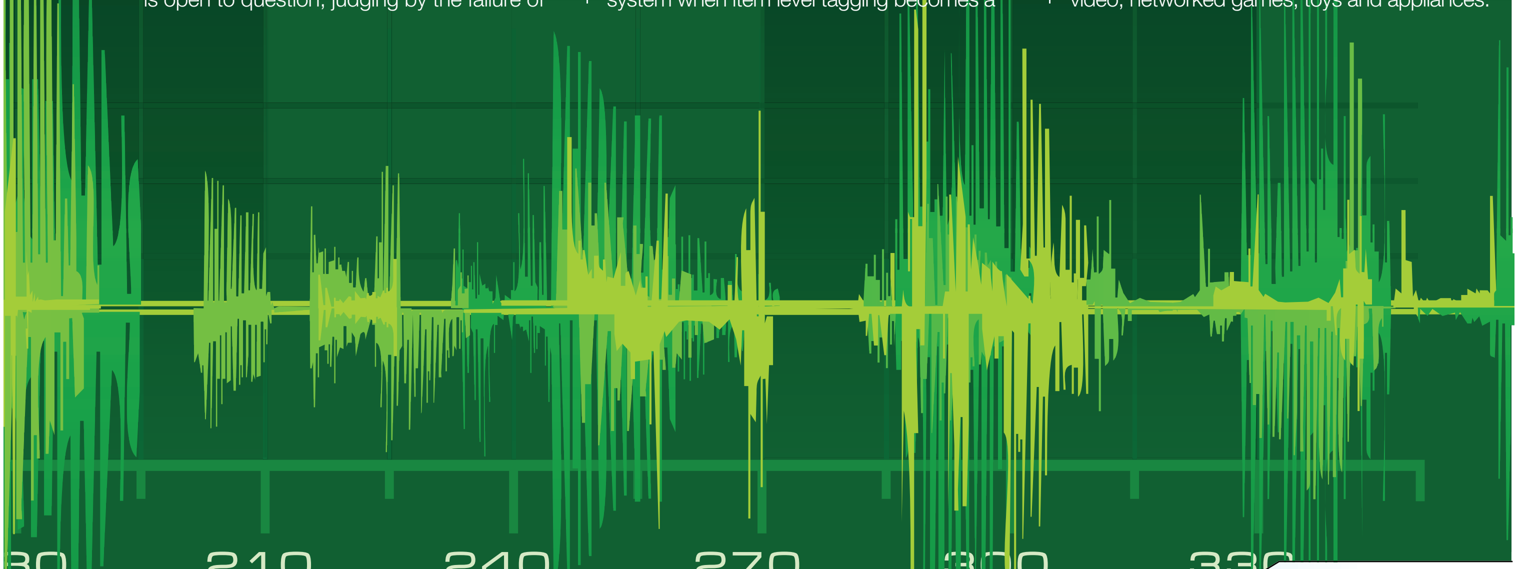
The lesson learnt from the introduction of the electric dynamo is being ignored by the current drive to pursue quick fixes, including the pursuit of one elusive standard.[3] Gobal leverage should be used to promote interoperability between select, partially adopted standards in a way that systems can interface seamlessly through translational mechanisms (drawing obvious analogies from human language). This approach is standards agnostic but could remain multistandard compliant. Sensors and RF technologies are enabling tools that detect, monitor or identify — but may not add real value unless the process or system generates decisionable information.

Ultrawideband (UWB)

Most RFID types (125 KHz, 13.56 MHz, 433 MHz, 868–915 MHz) possess a spatial capacity of 1 kbpspm^2 (kilobits per second per metre squared).[4] Spatial capacity focuses not only on bit rates for data transfer but also on the bit rates available in confined spaces (grocery stores) defined by short transmission ranges. Measured in bits per second per square metre, spatial capacity is a gauge of "data intensity" that is analogous to lumens per square metre (that determines the illumination intensity of a light source). The growing demand for greater wireless data capacity and the crowding of regulated radio frequencies (approved ISM spectra) will increasingly favour systems (spectra) that offer appreciable bit rates and will function despite noise, multipath interference and corruption when concentrated into smaller physical areas (stores, warehouses). Will spatial capacity limitations clog the 'interrogation' system when item level tagging becomes a reality? Some are exploring BlueTooth — with a spatial capacity of 30 kbpspm^2 — while asset management may use 802.11a protocol (5.15–5.35 GHz) with a spatial capacity of 55 kbpspm^2 (for example, spare metal parts in airline repair shops, such as Lufthansa Technik).

Quite a few companies have been exploring ultrawideband since its appearance on the scene in 1962. UWB spans several gigahertz of spectrum at very low power levels, below the noise floor of existing signalling environments. The spatial capacity of UWB is 1000 kbpspm^2 or 1000-fold more than 802.11b (WiFi). Conventional narrowband technology (802.11b, BlueTooth, 802.11a) relies on a base "carrier" wave that is modulated to embody a coded bit stream. Carrier waves are modified to incorporate digital data through amplitude, frequency or phase modulation. These mechanisms are, therefore, susceptible to interference and the coded bit stream (for example, electronic product code or EPC) could be decoded or intercepted, posing data security issues. UWB wireless technology uses no underlying carrier wave but modulates individual pulses either as bipolar or amplitude or pulse-position modulation (sends identical pulses but alters the transmission timing). UWB offers a pulse time of 300 picoseconds and covers a broad bandwidth, extending to several gigahertz.

UWB operates in picosecond bursts; hence, its power requirements are drastically lower (200 mW) when compared with 802.11b (500 mW) or 802.11a (2000 mW). The data rate for UWB (0.1–1.0 gbps^2) is staggering when compared with 802.11b (0.006 gbps^2). Sony and Intel, among others, are leading the research into the wireless transmission of data, video, networked games, toys and appliances.



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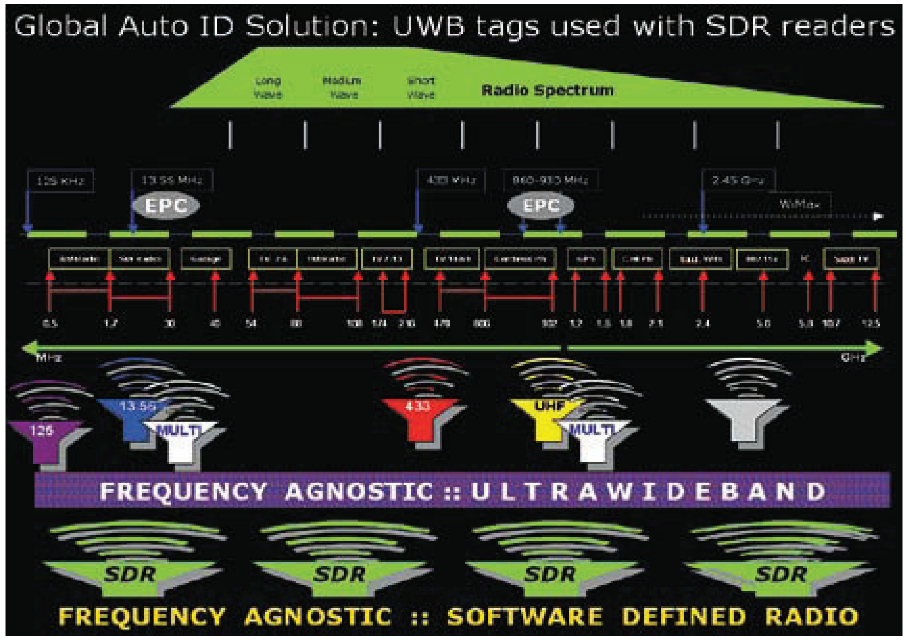

Today, we have robotic vacuum cleaners that clean the living room without ever touching the sofa and lawn mowers that tend the manicured garden without ever grazing the rose bush. The universal appeal of UWB is latent in its capability to offer a global standard. Without FCC-like country specific restrictions, an old technology like UWB still remains virgin for many possible applications and may be the only global wireless communication medium that may claim, someday, to be a truly global standard.

After 9/11, UWB transmitters (like RFID readers) were mounted on robots and used in search missions at the World Trade Center — because UWB is less hindered by metal (Coke cans or turbine spare parts) or concrete (buildings and warehouses). On 14 February 2002, the FCC gave qualified approval to use UWB in the range >960 MHz, 3.1–10.6 GHz and 22–29 GHz.[5] Limiting power also limits UWB efficacy and spectrum.

UWB-RFID active transponders are not cost-prohibitive, whereas transmitters are cheaper than 802.11b RFID readers because they do not need many analog components to fix, send and receive specific frequencies. The combination of UWB and narrowband technology to produce a passive UWB transponder may be a reality by combining UWB communication with a narrowband RFID tag.[6] Combining a narrowband receiver and a wideband transmitter in the tag optimizes the collection of RF energy on the receive channel, combined with the ultra-low power on the transmit channel. At the MAC layer, optimized conflict resolution algorithms allow multiple tags to communicate efficiently and effectively with the reader. Because of this algorithm, the channel is used efficiently by taking advantage of the principle of orthogonal frequency division multiplexing (OFDM). This results in an increased effective bandwidth that allows more tags to communicate with the reader. The similar use of OFDM to enhance fixed frequency RFID readers may be useful, too. Thus, utilization of narrowband downlink and wideband uplink communication enables wholly (passive) or partially battery-less tag designs to be manufactured at low cost.

Owing to the very broad frequency content of the transmitted UWB impulse, it is extremely resilient to path fading and enables readers to determine the location of tags. Thus, not only can UWB tags identify, they can also locate (for example, the movement of objects in a warehouse as well as the storage organization). Unlike traditional passive RFID tags, passive UWB tags use their accumulated power to transmit UWB impulses to the reader. Tags are rewriteable and can be programmed to have 64, 96 or 128 bits.[7]

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Despite the clear advantages of passive UWB RFID tags, in general, the dispute in the field stems from claims that UWB transmissions may interfere with the spectrum used by cell phones and air traffic controllers. FCC is investigating, but it is poised to open up even more of the spectrum for commercial UWB applications. Without the burden of license fees for spectrum usage, the commercial floodgates for UWB usage may be unstoppable, much to the chagrin of the telecom industry. MSSI is charting new territories and PulseLink has shown that SDR readers work with UWB chips.

Software Defined Radio (SDR)

The current thinking about using "readers" that are specific to one or more RF modes may not be a sustainable approach for the infrastructure necessary for object identification to become pervasive. Heterodyne readers that can read MHF (13.56 MHz) and UHF (902–956 MHz) tags cost about $5000. Now, consider the commonly used frequencies, RFID versus UWB, passive versus active, multiple standards (EPC, GTAG) and regional regulations (RF spectrum, emitted radiated power); taken in combination, it spawns several types of transponders and, to read the tags, a variety of readers is necessary. Multifrequency tags and readers may not adequately address the problem or reduce infrastructure cost. According to the current model, businesses dealing with objects from global partners must possess an infrastructure (several types of readers) that is capable of reading a plethora of tags. Readers or tag interrogators, in

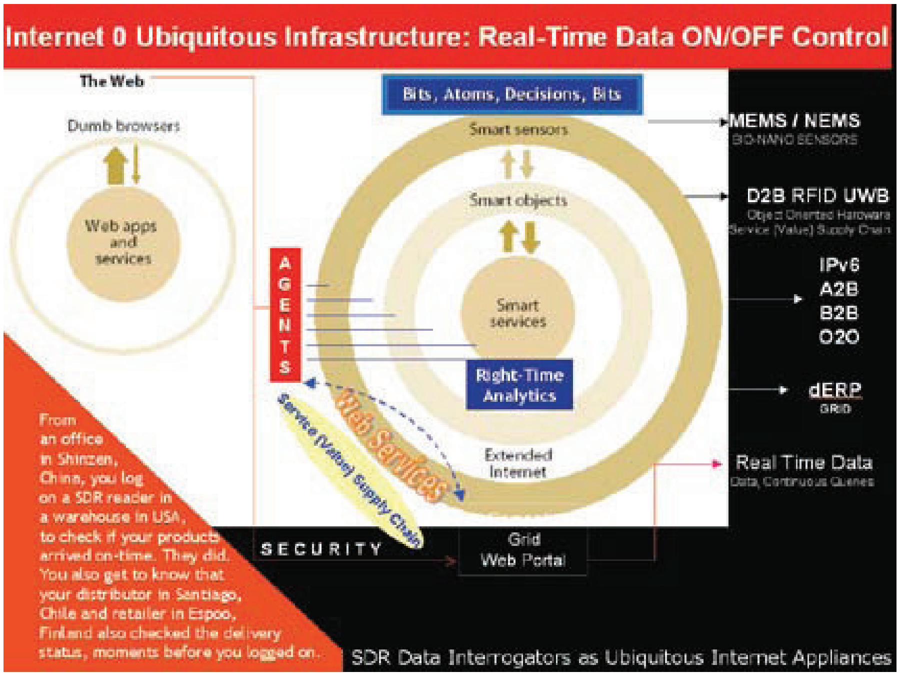

Figure 1: A ubiquitous systemic software infrastructure.

the future, must be as ubiquitous as a civil engineering infrastructure similar to electrical outlets, evolving to form the Internet of Devices (Interdev), with software as a part of the infrastructure that enables pervasive data acquisition as well as dissemination (transmission). Data and information sharing may be a reality if security enabled open source software is deployed as an infrastructure that responds to global interoperability. Control, security, updates and hardware improvements may be delivered via this ubiquitous systemic software infrastructure. It is this scenario that is outlined in Figure 1 where the reader in a warehouse is always 'on' but the ability to read certain objects (or not) is controlled through the software layer by the authorized user, and the authorizations allowed by the principal user. The 'views' of the contents of the warehouse is limited to objects that the user can 'read' by virtue of the preamble that must be exchanged and validated between the reader and tag (similar to the architecture embedded in EPC).

SDR is an at-hand solution that can deliver part of this ubiquitous infrastructure in a manner that will remain transponder hardware agnostic, with all modulations effected through the SDR operating systems (OS). This view, that of using SDR hardware (in some form) as ubiquitous RFID interrogators (in a refrigerator or in a warehouse), is the proposal based on the current understanding of software radio (SWR).[8] In 1991, the term "software defined radio" was coined to describe radio devices implemented in software and running on generic hardware. Because SDR is linked to global mobile telephony, an area of convergence between SWR infrastructure for real-time data and the delivery of real-time data as a service may evolve as a robust business for telecom providers.[9] A potential modus operandi using Internet protocol version six (IPv6) and a plausible revenue model is discussed in an earlier paper.[7]

Paradigm Shift: Identification of Information

The tools and technologies discussed above add significant costs to any operation. The justification for the investment necessary to connect bits to atoms has taken on a special significance in recent years, but it has been growing since the demise of the Cold War and continues to increase with the robust economic growth of the BRIC nations (Brazil, Russia, India, China). The Internet has facilitated the connectivity of the bits (data) that enables the creation of virtual maps of atoms (things). This 20th Century perspective of mapping the Physical World evolved in parallel with the ascent of the Information Age. The generation of raw data accelerated exponentially, partly because of the plethora of tools. Yet, productivity gains remain incremental. The necessity to identify objects began with the barcode in 1975 but soon created a surfeit of numbering systems, including the "e-barcode" or EPC (electronic product code).

As its name implies, EPC and other alphanumeric identification systems are associated with products; that is, finite objects or actual things. In the real world, raw data about an object or group of objects, in isolation, may not qualify as decisionable information or be less helpful for decision support systems or decision making processes aided by humans. Data about atoms (things) also include chemically synthesized moieties, such as small molecules designed by organic chemists for drug assays in pharmaceutical companies. However, standards such as EPC focus on products or objects — as the context of the barcode and EPC originates from the retail industry supply chain. Object data (atoms and products) must be combined with process (intangible in terms of atoms but bit-friendly) and logic must be applied to extract information, which may be subjected to further analysis.[10] Thus, data is not information. The Information Age, as appropriate as it may have been in the last century, may no longer be a useful description of the present era. Information, per se, is increasingly toothless.

For information to be of value, it must help the decision-making process, either through decision support systems or human-aided chaos. Useful or decisionable information may help transactions in business, healthcare or in a variety of other systems. Decisionable information in one domain, such as purchasing, may not be an end in itself. It may be necessary to couple that with other, equally valuable decisionable information, such as manufacturing. Thus, if the systems are interoperable, when information is taken from both the purchasing and manufacturing systems, it may offer guidance for buyers to initiate a requisition for raw materials in the ordering system. It is evident that systems must be connected for valuable information to be useful in the transactional space of interoperable decision systems. This spells the end of the Information Age.

The Systems Age aptly describes the growing necessity to connect information from a variety of sub-systems that may be related by the function being executed to deliver value. The appreciation of the significance of related information and the system of systems [SOS] interoperability approach is a theme that is central to future innovation in identification from the perspective of creating intelligent decision systems.[11] The broad spectrum of applicability of this fundamental principle may be appreciated through the vision of relativistic information that is important to business operations, information services, healthcare, biomedical sciences and research, including the core disciplines that drive industrial growth.[7] Globalization has catapulted the Systems Age to where the monolithic enterprise resource planning (ERP) systems and silo approaches must adapt or die.

The identification of objects in any global operation or within a system of systems framework (for example, healthcare) offers limited functionality. Identification must rise to a higher plane to address the identity of information that includes identification, which may be similar. The information flows of tangible and intangible elements are equally crucial to aid decision support in hierarchies of synergistic systems. For example, two individuals who are both named Mary Smith may have identical blood glucose levels (120 mg/dL). The identification of Mary Smith may be uniquely achieved through a social security number (SSN), but how do you number 120, which is identical in both instances? The combination of SSN with 120 creates a unique identity that includes identification about an object (human being) but also provides a higher plane of information when taken together with a non-physical or intangible piece of raw data.

The volume of data and the nature and volume of related data and information is vast. High volume data has distinct advantages but the resulting decisions may be distributed over several systems.[12] Interoperability between systems and success in local, as well as global, decision making, demands the management of information that is identifiable, yet remains platform agnostic and multistandards compliant.[13] The identification of information must address the need for the unique identification of decisions that may involve hierarchical layers of data, information and decision, each with its unique identification, in a local or geographically dispersed system of systems.

This paradigm shift offers the potential to create new products and services to drive future economic growth. The convergence of tools, technologies, concepts and disciplines necessary to transform this vision into reality demands the cross-pollination of global institutions to stimulate collective innovation, in addition to worldwide academic-industry partnerships and core research programmes with a critical mass of faculty and students capable of addressing the challenges that are known and the known unknowns, not to mention the unknown unknowns.

Temporary Conclusion

Globalization demands innovation in standards agnostic information identification because the identification of physical objects is insufficient for decision support. The myopic view of auto ID and numbering of objects is justifiable for an IT company if it must focus on the delivery of dividends for shareholders in the next quarter. But, the haste to reap the mythical mirage of "low hanging fruit" may be detrimental to the informed vision of sustainable future economic growth. Guiding the latter is the responsibility of academic foresight and academia as the purveyors of civilization. •

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