The Value of Open Standards to Transportation

Peter O'Reilly
Northeastern University

Prepared for The Rudin Center, New York University
Leveraging Technology for Transportation
June 16, 2010

Abstract

In this paper we present the case for open standards in the transportation industry especially from a business and economic perspective. We show that the use of open standards in the telecommunication industry has helped fuel that industry's enormous growth in the past quarter-century. We believe that the adoption of open standards in all aspects of the transportation industry will similarly provide significant cost savings and opportunities for growth.

1. Introduction & overview of paper

In this paper, we demonstrate the value of open technical standards especially in the telecommunications industry and argue that the adoption of open standards can provide equal value to the transportation industry.

After providing a brief historical perspective on standards, we explain what we mean by "open standards." We then review how standards get developed and identify some issues with the process. Proprietary solutions are the antithetical opposite of open standards-based solutions. Having discussed the pitfalls of proprietary solutions, we identify the major advantages of open standards from the technical, economic and legal perspectives, as well as some potential drawbacks of standards-based solutions. We then explain why detailed open technical standards have been enormously successful in the telecommunications and IT industries. Finally we address standards specific to the transportation industry, notably, the CBTC standards for rail control and signaling, and how CBTC systems are actually being deployed. We review the involvement of APTA in developing transportation standards, as well as open standards for electronic payment, especially contactless smart cards.

2. Open standards

Some history

The value of standards in U.S. industry first became apparent with the advent of precision manufacturing in the early part of the 19th century. It was realized that the cost of production decreased significantly with the availability of interchangeable parts. Manufacturers started to develop products that conformed to a specification. Early industries that took advantage of the availability of "interchangeable parts" were manufacturers of guns, clocks, bicycles and sewing machines [1].

In certain cases, the absence of a standard may lead to a disaster or major calamity. A well-known example is the incompatibility of firehose couplings in early 20th century America. In 1904 a fire broke out in the basement of a building in Baltimore. The fire spread quickly until it occupied an 80-block area of the city. To help combat the flames, fire engines were sent from New York, Philadelphia and Washington DC. However, their fire hoses did not fit the hydrants in Baltimore and the fire raged for more than 30 hours with over 2500 buildings destroyed. Subsequently a standard (11 threads per inch) was established [2].

Another well-known example was the incompatibility of railroad gauges throughout the U.S. prior to the Civil War. While the North had an integrated rail system using a single gauge, southern railroads used a multiplicity of gauges. It has been asserted that was the "real reason the South lost the Civil War" [3]. Subsequently in 1886, a gauge of 4 feet 8 ½ inches became the U.S. standard.

While the absence of a standard may lead on occasion to a disaster, what standards facilitate more generally is an efficient economy through the decomposition of often complex systems into subsystems and components with standard interfaces – as, for example, standardized dimensions for basic nuts, bolts, screws, etc.

Terminology

Standards come in all shapes of sizes. On the one hand, we may have national standards (sometimes mandated), eg, thread of firehose couplings; on the other extreme, we may have *de facto* standards which usually come from a single vendor (eg, the QWERTY keyboard, MS Word, PDF document format, MP3 audio format). Some standards come from industry groups (eg, the 3G wireless standards from the 3GPP and 3GPP2 groups, and Internet standards from the IETF), others from professional organizations such as the IEEE (eg, the Ethernet local area network standard).

The interpretation of the term "open standard" is not uniform. In the telecommunications and networking industry, the IETF and ITU-T use definitions of an open standard which allow "reasonable and non-discriminatory" patent licensing fee requirements.

On the other hand, many academics and governments (notably the European Union) preclude the use of any licensing fees in their definitions of "open standards." Clearly the OSS (Open Source Software) movement – which encourages the free availability of source code – is at the extreme of open standards and open systems [4].

For the remainder of this paper, we will use the term *open standard* to denote a standard that has been developed by any industry group or official standards-developing organization. So-called *de facto* standards developed by a single vendor or a closed group of vendors are specifically excluded. However, standards that allow royalty and licensing fees are included within our definition. Without some sort of reward system, there may be no incentive for a vendor to support innovation. Also, standards processes that exclude any kind of reward structure may encourage competing proprietary solutions and cause market fragmentation.

A good example here is Qualcomm for its innovation in the development of the CDMA technology which is at the core of the broadband 3G wireless technology. Similarly, vendors who develop innovative speech and video codecs need to be rewarded. If patented technologies were to be excluded from the standards process, those standards may very well be inferior technically to proprietary solutions. Of course, these patented technologies need to be made available to other vendors "on reasonable and non-discriminatory terms."

3. The standards development process

Open standards may be developed in a number of ways.

Many standards are developed under the auspices of an official (*de jure*) standards development organization (SDO). International standards organizations include the ISO (International Standards Organization) the ITU (International Telecommunications Union), and the International Electrotechnical Commission (IEC) – these are all fairly broad standards-setting organizations. More specialized international standards groups are the 3GPP and 3GPP2, the Universal Postal Union and the American Petroleum Institute.

Examples of regional and national *de jure* standards organizations are ETSI (European Telecommunications Standards Institute) and ANSI (American National Standards Institute), respectively. Within the U.S., the U.S. government's standards agency NIST (the National Institute of Standards and Technology) cooperates with ANSI to develop standards for the United States.

Sometimes a SDO has semi-official status. For example, the IETF (internet Engineering Taskforce) establishes Internet standards (termed RFCs), the World Wide Web Consortium (W3C) develops standards for HTML, XML, etc., and the IEEE 802 Committee develops local and metropolitan area network access standards such as Ethernet, Wi-Fi, and WiMAX.

As official standards processes can often be quite slow, industry groups often initiate a highly focused industry forum, consortium or alliance. Some examples in the telecom industry include the ATM Forum, the Metro Ethernet Forum (MEF), the Femto Forum, the Wi-Fi Alliance and the ZigBee Alliance. The primary contributors to these efforts are usually vendors who see it in their interests to collaborate to create a single standard. Quite frequently, the outputs of these industry efforts are adopted by more formal standards groups.

In a number of cases, users get together in User Groups to ensure that their requirements are covered by the standard under development. In other cases, vendors may be alert to the networking needs of their customers (the end users) and successfully “capture” their requirements.

As indicated in Figure 1, User Groups, with early access to working drafts, can review errors and propose other changes in a manner that provides a faster consensus. This results in the vendors receiving developed standards that address implementation guidelines and test procedures, providing a higher degree of technology confidence and less likelihood of “buyer’s remorse.”

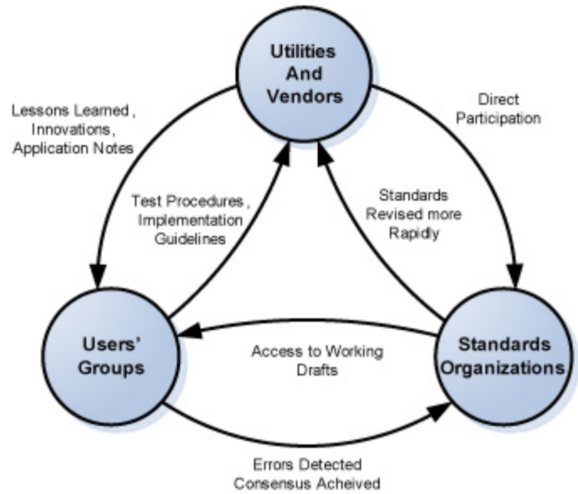

Figure 1: Potential Interactions between User Groups, Vendors and SDOs

In the software industry, technologies developed by a single vendor are often opened up to the industry at large under the "rising tide lifts all boats" belief. Although Sun Microsystems was the original developer of the Java programming language, updates to the Java platform are now managed by the Java Community Process, which is open to all interested parties.

On the other hand, some efforts are established to specifically counter the dominance of a single industry player, notably Microsoft. An example is OpenOffice.org, an open standard competitor to MS Office, funded primarily by Oracle but also supported by Google, IBM, RedHat, Novell and others.

Issues with the standards development process

One of the major issues with standards is that they can take a long time to develop. Some SDOs are extremely process-oriented with subcommittees, etc. More importantly, standards generally require consensus-building between all the parties involved. Some of the vendors involved in the process may have a proprietary solution of their own already in the marketplace, so they have little incentive to move the process along.

For many years, it was generally recognized in that standards development organizations (SDOs) in the telecom/networking area, such as the ITU-T and the 3GPP, that focused on system-level solutions took much longer to develop technical standards that SDOs that focused on component-level solutions such as the IEEE 802 Committee (responsible for LAN and WLAN standards) and even the IETF. System-level solutions necessarily make the standards more complex and also take longer for consensus to be achieved. Consequently some standards, such as ISDN and the OSI model for communications (developed by the ISO), never gained significant acceptance and were supplanted by competing standards. In recent years the 3GPP and 3GPP2 group have become focused in their activities and have also encouraged the subsumption of "standards" developed by much smaller industry fora (eg, the home base station standard developed by the FemtoForum).

On occasions, when it is apparent that a consensus does not exist, multiple incompatible standards may end up being approved. At one point, digital cellular phones in the U.S. could be one of three types – two ANSI standards (TDMA and CDMA versions) and a European standard (GSM). Different wireless carriers used different standards – however, the only time consumers may have had a problem is when they roamed onto a network where their phone technology, or a default earlier standard (ie, AMPS), was not supported.

It is possible that the length of the process may allow proprietary solutions to preempt the developing standard. In general, this becomes an issue only if the vendor involved is dominant; more commonly, products that reach the market before the standard process has been consolidated label their product as pre-standard; in essence, they are usually making a commitment to adapt their product to the standard when it matures.

4. What's wrong with proprietary solutions?

The basic argument in favor of proprietary solutions is the one-stop shopping ease of purchase and the security of having all-encompassing technical resources for system integration and ongoing system maintenance. For large or complex systems, this can be an important benefit, especially to customers with no or minimal internal technical resources.

The basic argument <u>agains</u>t proprietary solutions is the proprietary lock on the customer and how the lack of competition almost certainly results in higher replacement costs that escalate during the ownership life cycle. When a customer acquires a proprietary solution, they are generally subject to what economists term the "lock-in" phenomenon, and its associated "switching" costs. Everyday consumer examples of lock-in are store gift certificates, printer cartridges, and disposable razor blades. High switching costs are endemic in high-tech industries and are frequently so large that changing suppliers is virtually unthinkable, causing a severe case of vendor lock-in.

For example, when a customer switches cars from a GM model to Toyota (say), the change is relatively painless. But if you switch your operating system from Windows to Linux or Mac OS X, it can be very costly. Not only will you probably have to change document formats, applications software, etc but you will have to invest substantial time and effort in learning a new OS. Changing software environments in the enterprise is also very costly. A study reported in [5] notes that the true cost of installing an Enterprise Resource Planning (ERP) system like SAP was eleven times greater than the purchase price of the software itself due to the cost of necessary upgrades to the infrastructure, consultants, retraining, etc.

Proprietary solutions may involve either commercial off the shelf (COTS) or customized products. Customized solutions will always be more expensive but either way the likelihood of lock-in to the supplier is extremely high with significant associated switching costs, especially in the telecommunication, information and transportation industries.

For instance, telecommunication carriers have been locked-in for many years to their switching vendors. If a carrier acquired a 5ESS switch from AT&T in the mid-1980s (later Lucent and now Alcatel-Lucent) chances are it is still using that 5ESS and all its many upgrades – both hardware and software – over a quarter century later.

Shapiro & Varian [6] identify a total of seven economic patterns that can lead to lock-in. The five primary patterns are:

- contractual commitments
- durable equipment and aftermarkets
- brand-specific training
- information and databases
- specialized suppliers

With durable equipment, switching costs tend to decrease over time due to depreciation; however, most durable equipment requires follow-on purchases, often of other durable equipment. With brand-specific training, switching costs tend to increase with time as personnel become more and more familiar with the existing system. It should be noted that learning a new system as part of switching has both direct costs and loss of productivity. Similarly as the amount of data in some specified format grows, the cost of moving to another software platform increases significantly. With a specialized supplier, the customer is essentially hostage to that supplier – hence a dual sourcing is sometimes used by customers as a protection mechanism. Other economic patterns are search costs and loyalty programs.

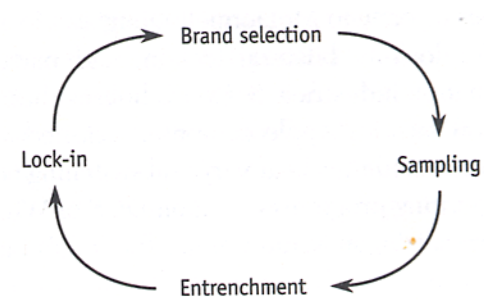

Figure 2: The Lock-in Cycle [6]

Shapiro & Varian also provide a lock-in cycle (Figure 2) moving from a “brand selection” phase where a customer purchases a new software system (say) very often at a low entry cost. Costs are often spread over the lifecycle with perhaps a multiyear service contract. This is followed by perhaps a sampling phase where the vendor offers some free inducements (eg, free software applications) to an entrenchment phase where the customer may make so-called complementary investments (eg, other proprietary applications, upgrades, external devices and systems, etc). At this point, the customer is likely to be truly locked-in and when the brand selection point is reached again, the switching cost may have become prohibitively expensive; the replacement cost alone which has escalated during the ownership life cycle may be extremely high.

Switching costs in the information services industry in particular tend to increase with time. As the amount of data and number of proprietary applications grow, the cost of moving to another software platform increases significantly. As emphasized in [6] and by other economists, failure to understand switching costs leave customers vulnerable to opportunistic behavior by their suppliers.

5. Advantages, and some disadvantages, of open standards

Open standards provide economic, technical and even legal value.

Economic value

The use of standards in manufacturing produces considerable cost savings due to economies of scale. Standardization - especially with the interchangeability of parts and components – facilitates production and industry growth and results in cost savings to both producers and consumers.

For example, in the early days of the US auto industry, smaller firms were interested in standardization in order to achieve sufficient economies of scale to compete with GM and Ford [7]. The Society of Automotive Engineers carried out the standardization process which yielded many costs savings to producers; Ford and GM eventually saw the advantages of standardization and participated in the effort, eventually playing a major role in the standardization of automobile parts.

In general the availability of standards reduces uncertainty in the marketplace, thereby facilitating industry growth, and usually providing cost savings to consumers.

In the case of consumer products and services, in particular, acceptance of a compatible standard tends to amplify what economists call “network externalities.” A network effect or externality is the effect that one user of a product or service has on the value of that product to other people. When a positive network effect is present, the value of a product or service increases as more people use it. The classic example of a positive network externality is the telephone. The more people own telephones, the more valuable the telephone is to each owner. Online social networks like Facebook are also more useful the more users join. (A negative network effect is pollution caused by cars.) In general, compatibility standards in the telecommunications and IT sectors expand consumer markets and promote technological progress through externality effects.

However, it should be noted that the above argument can also apply when there is widespread adoption of a dominant proprietary system product or service, eg, the Windows operating system. Acceptance of a *de facto* standard also amplifies network effects and causes widespread lock-in. It’s necessary here to distinguish here between technology and vendor lock-in. When the market is locked-in to a standard, this is technology lock-in; when it’s a proprietary system, it’s obviously vendor lock-in. The latter is clearly more serious. In either case, however, it becomes difficult to switch to another standard if it’s not economically advantageous to do so.

Technical value

By definition, open standards support interoperability in a multivendor environment. A solution based on open standards allows the customer to replace subsystems with products of other vendors on an ongoing basis.

Another reason to support an open standards-based solution is to have access to innovative solutions. In general, no one organization has all the innovation – many of the standards organizations encourage innovative companies to submit new technologies for standardization and thus provide the users of the standard access to this innovation at much lower cost than in an equivalent closed solution. Tom Friedman in *The World is Flat* [8] argues that

> *Standards don't eliminate innovation, they just allow you to focus it. They allow you to focus on where the real value lies, which is usually everything you can add above and around the standard*.

For software systems, it has been argued [9] that open software standards support security as they not only support key technical approaches for security but create economic conditions necessary for creating secure components and systems. In open systems, users can choose between competing suppliers. In closed systems, suppliers have little incentive to maintain security – and other features – at a high level, as customers often face high switching costs.

Finally, standards are rarely static – they are constantly being enhanced. Thus a standards-based technology solution will naturally receive upgrades and enhanced features. Assuming that the standard deployed is a living, active standard, customers are ensured of being in the mainstream and migration within that standard is provided as part of a general industry trend. On the other hand, proprietary solutions – especially custom solutions – tend to remain static until there are some external drivers; customers often end up with systems that lag the rest of the industry in performance, security, etc.

Legal value

By themselves standards do not have any legal force. However, when a standard is cited by some legal entity or a government regulation, things are different. Notably, the Federal Railway Administration (FRA) has cited a number of APTA standards. In fact, use of consensus standards is strongly encouraged by Public Law 104-113 of the Congress of the United States:

> *In general—Except as provided in paragraph (3) of this subsection, all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments.*

A standard also has legal force when a procurement specification requires compliance with that standard. If a technical specification cites a particular standard, then its use becomes part of that contract. In fact, <u>not</u> using an open standard in developing specifications may create a potential liability risk, in the public transportation industry for instance – unless of course a documented engineering evaluation clearly indicates that the standard does not meet one or more of the system requirements.

Some disadvantages
As standards are generally consensus-based, they can sometimes take a long time to reach the marketplace – especially for standards that provide system solutions. It is often a highly political-economic process with stages of coordination, negotiation, coalition-building, and consensus-making. However, as discussed, methods to shorten the process have been created. The resultant cost of developing, testing and implementing standards can also be high. However, although compromises are inevitable as part of the process, the quality of the end-product, as it were, is usually quite high.

The standards process does not guarantee that the "best" technology wins out. It is possible that customers may end up with less-than-optimal technology. In a marketplace, where multiple proprietary solutions compete, customers have the option of choosing between different technologies. In particular, consumers have the option during a "standards battle", eg, the famous video format wars (VHS vs. Betamax, and more recently, Blu-ray vs. HD DVD), of experimenting with different technologies. However, choice often leads to confusion, creates uncertainty, and hinders the development of the market. On the other hand, *de facto* standards wars can be good for consumers as competition generally drives prices down.

As stated earlier, the primary argument in favor of proprietary closed solutions is the one-stop shopping ease of purchase and the comfort in having a single entity (ie, the vendor) take care of system integration and ongoing system maintenance. When open systems are deployed, the customer will either need to take care of system integration themselves or hire a third party to fulfill this function. Similarly, the customer will need to work with multiple suppliers to support ongoing maintenance, installation of upgrades, etc – or again outsource this responsibility to a third party.

6. Success of standards in the telecom and IT industries

The telecommunication / networking and IT industries have grown enormously in the past quarter century with the development of the Internet and the Web, broadband access (landline and wireless), the proliferation of mobile devices, etc.

The proliferation of open standards in these industries has been one of the primary factors that has helped fuel this enormous growth. Prior to the breakup of the Bell System in the early 1980s, the public switched telephone network was based on *de facto* standards developed by the Bell System (AT&T). This was necessary to facilitate interoperability between the Bell System and the few independent carriers in the U.S. and also interoperability with carriers from other countries. At that time this interoperability was primarily with transmission and signaling systems. (Signaling is that network-wide capability that enables telephone calls to be established on an end-to-end basis.) Since divestiture, this interoperability has been facilitated by both international standards groups such as the ITU (previously the CCITT) and national standards organizations such as ANSI.

Major successes of the ITU and ANSI over the past quarter-century have included digital transport systems (SONET in North America and SDH internationally). Standards in telecommunications have never required a "one size fits all" philosophy. While SONET and SDH, for example, are quite different in many respects they have much in common, and most importantly, are inter-operable. Similarly while Signaling System No. 7 (SS7) is the international standard for signaling, it has many local flavors, but again the systems are completely interoperable. Otherwise clearly we wouldn't be able to make telephone calls across the globe.

On the data networking side, the ubiquity of the Internet Protocol (IP) today – both in the public arena (the Internet) and in private networks – would seem to indicate that an internationally accepted, open standard was the obvious choice. However, this was not always so. For many years proprietary solutions, notably IBM's SNA, were the prime business solution. From the mid 1970s to the early1990s, IBM dominated the corporate computer world and enterprise data networking. SNA at one point had 98% of the Fortune 50 market. IBM not only provided a complete network solution but access to a wide range of (proprietary) application services. Open standard networking solutions (such as the ITU's X.25) struggled for many years to compete with closed vendor solutions. As it was said at the time, you could never get fired for choosing an IBM business solution.

In many ways, the end of closed solutions came with the move away from mainframe computers towards minicomputers ending with the proliferation of personal computers we have today. This was aided and abetted by the success of Ethernet as a LAN technology that allowed these PCs to communicate and share resources. Ethernet, based on the IEEE 802.3 standard, provided a low-cost highly reconfigurable solution to the interconnection of computers in the workplace. Proprietary solutions such as Novell's IPX/SPX were simply unable to compete.

The importance of open standards in transforming IT over the past couple of decades also cannot be understated. Open standards have significantly reduced the cost of automating back-office office functions such as service provisioning, ordering, billing, distribution, etc. as well as increasing productivity in the workplace. Unsurprisingly, Friedman [8] regards workflow software and supply chaining, both based on ubiquitous software standards such as XML, SOAP, etc, as two of the ten forces that "flattened the world."

Open technical standards, especially in the IT area, are strongly linked to open architectures, namely, architectures that decompose systems into a set of modular subsystems. Open standards do not define how these subsystems or components are designed; instead standards focus on the interfaces between these subsystems. Within an open architecture, it is the interfaces that define the functional, spatial, physical and non-physical nature of individual modules, and the way the modules interact with each other as part of the complete system.

Similarly, open standards in telecom and networking – irrespective of whether they are developed by the ITU, the IETF or the IEEE 802 Committee – never define what systems do and how they do it. In this case, standards define the communication protocols that flow across the interfaces (sometimes termed reference points) between functions or systems. Sometimes a vendor may choose to provide multiple functions inside a single system (or "box") so that a reference point becomes internal to the system. This is very often a viable market offering; in the end, the market decides.

Even when the interface between two systems or subsystems is compatible with a standard, a service provider or carrier will sometimes choose to deploy systems from the same vendor, instead of doing a "mix and match." Even when products claim compatibility with a standard, system integration can be sometimes tedious as vendors may interpret aspects of a standard somewhat differently or a vendor may not implement all of the functionality required by the customer's application. When a single vendor is chosen, the integration process is likely to be a lot smoother and less "fingerpointing" is likely to happen! This should be regarded as a pragmatic approach and not as a negation of having open interfaces.

The standards process is not always successful

While the vast majority of standards in the telecom and networking industries have been very successful – in fact, many of them enormously so – there have been a few occasions when real success was not attained. A notable example was the Intelligent Networks (IN) initiative in the 1990s.

The issue was the switching systems used by the landline PSTN carriers (today: AT&T, Verizon, Qwest) to not only switch telephone calls but also to provide so-called vertical or enhanced services (eg, call waiting, call forwarding, etc). Prior to that period, the switch vendors (eg, Lucent, Nortel, Siemens, etc) provided all those services. However the switching systems were all extremely closed and the customers (ie, the carriers) had to wait an extremely long time – usually a number of years – for any new services or features to be provided. These systems were also extremely expensive to acquire, maintain and modify with a 20-year depreciation period so that the carriers were truly locked into these products.

The goal of the Intelligent Networks initiative was to open up these closed systems so that 3rd parties could develop services and features for the carriers. This required the development and standardization of so-called "call models" as well as interfaces and protocols between the switches and external platforms. Of course this initiative, which was driven by the carriers, required the active participation of the switch vendors. In theory, the vendors were willing participants; in practice the process slowed down so that only a small window into the operation of call processing in the systems was opened. The reason may have been as much lack of modularity of the software code as vendor reluctance to open their systems up.

The inability of the landline carriers to provide new enhanced services in a timely, cost-effective manner was partially responsible for the huge success of the cellular industry and the corresponding decline of landline revenues in recent years. However, to be fair, not all blame for the problems of the landline carriers can be placed on their vendors. The carriers themselves and the regulatory framework in which they have operated must also shoulder quite a bit of the responsibility.

In hindsight, this may have been very much a pyrrhic victory for the switch vendors as landline carriers across the globe are not evolving these systems any further. Instead they are now beginning the process of replacing these circuit-switched platforms with IP-based routers and service platforms.

7. Standards in the transportation industry

In this section, we discuss standards specific to the transportation industry. Like most industries, companies in this sector have associated telecommunication/networking infrastructures and information systems, in which the issues of proprietary or standards-based solutions are no different than elsewhere.

As in other industries, open interfaces should be important to transit operators. For example, rail cars may be expected to last 30-40 years. When spares are needed but the original vendor is no longer in business or wants to support its product, the benefits of open interfaces become clear.

As discussed earlier, one of the earliest examples of the value of standards actually came from the rail transportation industry, namely, the width of rail gauges. Unfortunately a universal standard for rail gauges is not yet agreed; in a country as small as Switzerland today, 12 different gauges are used (this includes funiculars, trams, and private rail). So efforts at achieving widespread standards still have some distance to go.

Engineering standards

Many different professional engineering organizations (notably, IEEE, ASME and ASCE) are involved in developing technical standards for the rail transportation industry. In fact, these organizations collaborate on a joint conference each year, termed the Joint Rail Conference (JRC). Naturally the IEEE focuses on electrical/electronic issues (eg, signaling, control and communications) while ASME and ASCE deal with mechanical and structural issues, respectively.

We will focus first on standards related to transportation control and signaling systems, as opposed to standards for rail gauges, platform heights, carriage dimensions, etc. The IEEE RTVISC (Rail Transit Vehicle Interface Standards Committee) has developed a series of related standards for Communications-Based Train Control (CBTC) systems [10, 11, 12]. In particular, performance and functional requirements for CBTC systems have been established [10], including requirements for Automatic Train Operation (ATO), Automatic Train Protection (ATP) and Automatic Train Supervision (ATS), although actual CBTC systems do not necessarily have to provide all these functions.

As indicated, these standards – unlike most communication, networking and information systems standards – define performance and functional requirements, not interface requirements – with user interfaces being the notable exception. This unfortunately limits the practical value of these standards. In fact, as can be seen from Figure 3, all of the communications interfaces are absorbed in a single "subsystem," namely, CBTC Data Communications Equipment.

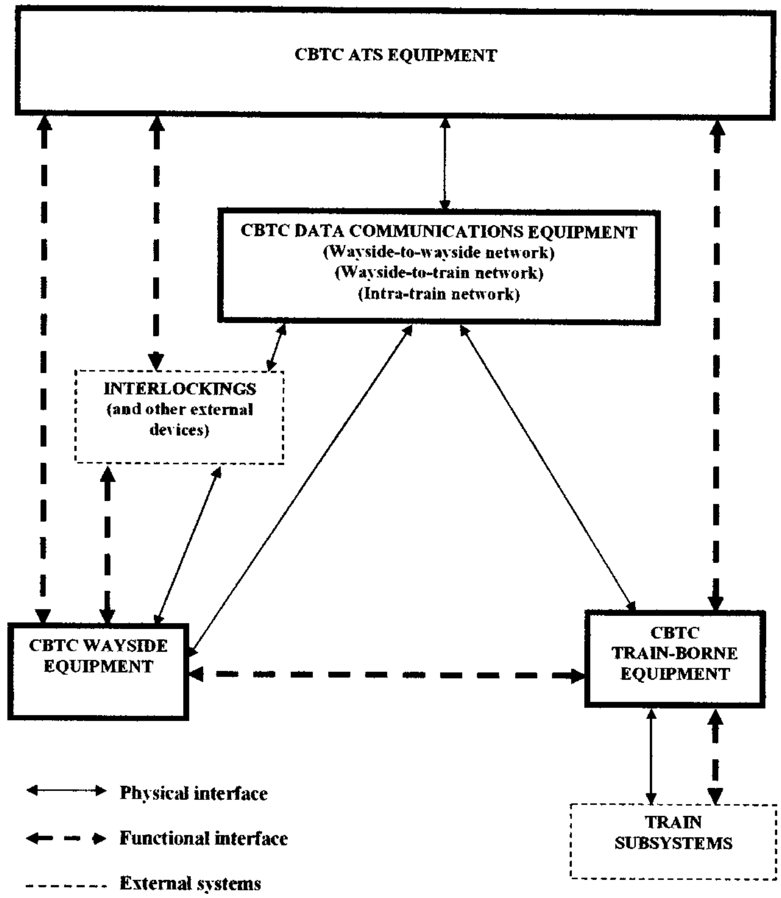

Figure 3: Major CBTC Subsystems in IEEE Std. 1473.3-2008 [11]

CBTC systems have been deployed across the globe, although adoption in the U.S has been very slow. In the absence of available interface standards, NYCT uses a novel "leader-follower" procurement approach [13] using multiple vendors; other worldwide CBTC deployments appear to be all single-vendor solutions. The NYCT lead contractor (chosen to be Siemens) is responsible for developing interface and interoperability specifications. The "leader" and other vendors ("followers") then develop compatible systems and demonstrate the common interoperability of their systems.

NYCT requires interoperability at three different levels as indicated in Figure 4: interoperability between carborne and wayside equipment, interoperability between 4-car trains equipped by different CBTC vendors, and interoperability between adjacent wayside equipment supplied by different contractors. It is important to note that no interoperability for the radio interface is required – data communications equipment (as developed by Siemens) is regarded as a common subsystem for all vendors.

NYCT has deployed CBTC on the BMT Canarsie line as a pilot program and is continuing with the Siemens solution on the IRT Flushing line with the Queens Boulevard line next up. As would be expected, not all major suppliers have been enthusiastic to be in a "follower" role, and thus this approach, with a set of interfaces controlled by a single vendor, runs the risk of heading towards essentially a single vendor solution. From an economic perspective, this is not that different from a completely closed solution. At the moment only one other vendor, Thales, is involved in CBTC deployment in the NYCT system. (Thales has adapted their SelTrac solution to meet Siemens' interface requirements.)

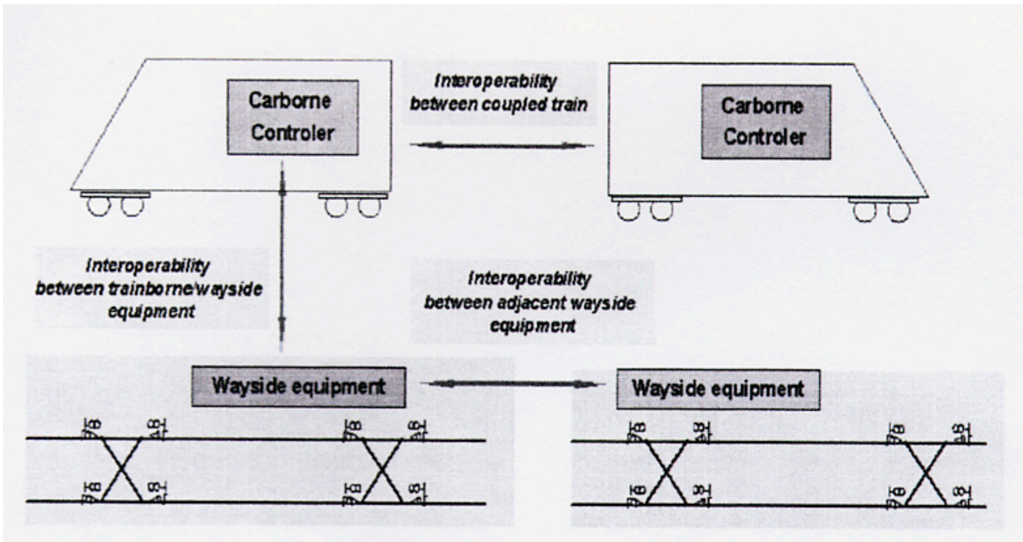

Figure 4: NYCT Interoperability

Most CBTC systems deployed elsewhere (eg, Thales' SelTrac) use standard protocols between the different components of a CBTC system, although the application-level messages are of course proprietary. In the NYCT solution, the wayside-to-train radio interface is a proprietary (Siemens) technology; in most other CBTC systems deployed, the IEEE 802.11 WLAN standard is generally used for this radio interface. (The 802.11 FHSS version in particular is well-suited to supporting trains moving at high-speed.)

Other IEEE standards include two versions of an Open-Source Communications Protocol for Railway Vehicles [14], namely IEEE-1473-L (LonWorks) and IEEE-1473-T (TCN). Both deal with communication between different carriages of a train with Lonworks the protocol primarily deployed in the U.S. A summary of standards developed by the IEEE RTVISC is given in [15].

Apart from those areas already addressed by IEEE/ASME/ASCE standards, there is the potential for the widespread use of technical standards in the rail transportation industry. The MODTRAIN project in Europe [16] illustrates this potential. (MODTRAIN represents *Innovative Modular Vehicle Concepts for an Integrated European Railway System*.) Over the past decade the EU partly funded MODTRAIN as a multiyear project (budget of about €30.4 million) which aimed at "defining the necessary functional, electrical and mechanical interfaces and validation procedures to deliver the range of interchangeable modules, which will form the basis for the next generation of intercity trains and universal locomotives." As a starting point, MODTRAIN concentrated on fixed-formation passenger trains and universal locomotives capable of 200 km/h or more. The project spawned subprojects which focused on running gear, control & monitoring systems, on-board power systems, man-machine & train-to-train interfaces, and brake system performance. The impact of this project on future train systems is unclear at this point.

APTA standards

Another organization developing standards for the transit industry is the American Public Transportation Association (APTA). APTA became involved in standards initially at the request of federal safety oversight organizations. However, it has become more heavily involved in standards claiming that existing standards developments organizations "were not interested in or not capable of meeting the transit industry's need for standards." While the IEEE, ASME and ASCE focus on technical (ie, engineering) standards, APT has developed standards and recommended practices for rail transit systems [17] in areas such as:

- vehicle inspection and maintenance
- operating practices
- fixed structures inspection and maintenance
- rail grade crossings, and
- signals and communications inspection and maintenance

Similar standards and recommended practices have been developed for bus transit systems, rail passenger equipment, universal transit farecards, and security. It should be noted that the vast majority of these documents provide recommended practices only; furthermore, the relatively few actual standards <u>not</u> limited to inspection and maintenance deal with construction issues, eg, a standard for "row-to-row seating in commuter rail cars." In summary, most of these standards and guidelines appear to deal with safety issues although a few deal with procurement (buses only) and farecards (ie, contactless cards – see below).

To illustrate what APTA is currently interested in, the draft standards currently out for public comment deal with:

- gap safety management
- fencing systems
- security lighting
- inspection of carryon items
- Bus Rapid Transit (BRT) running ways, service design, operations, ITS, and branding

APTA has even moved into the IT area with a standard on "Transit Communications Interface Profiles (TCIP)" and a draft recommended practice (currently out for public comment) on security in control and communications systems. The TCIP standard [18] purports to define interfaces between different business systems. For example, the Transit Business System module in Figure 5 may be decomposed into submodules representing a fare system, a scheduling system, a customer service system, etc. TCIP provides building blocks for interfaces for several business areas:

- Common Public Transport
- Scheduling
- Passenger Information
- Transit Signal Priority
- Control Center
- Onboard Systems
- Spatial Referencing
- Fare Collection

All the above business areas are approved in the current version of the standard (APTA-TCIP-S-01 3.0.3, dated Jan 2009), with the exception of Fare Collection. These standards are highly detailed specifying TCIP message encoding, TCIP dialog patterns, and TCIP conformance requirements, as well as annexes that provide both data element and TCIP message definitions in ASN.1, and TCIP XML schema.

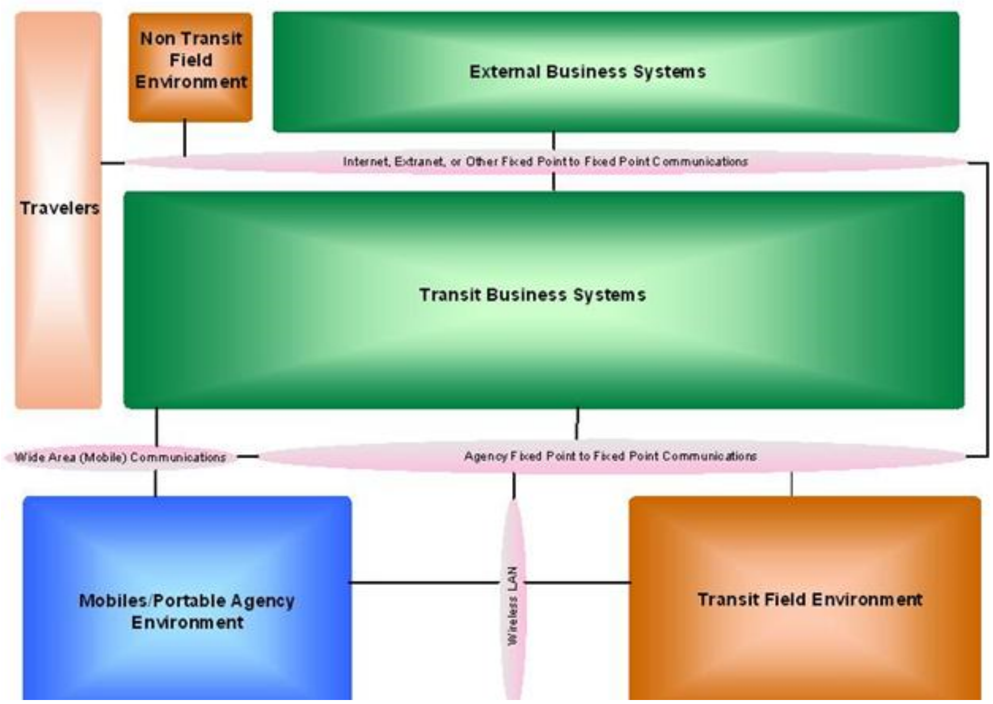

Figure 5: Top Level Physical TCIP Model Architecture

The APTA TCIP is heavily based on earlier TCIP work performed by ITE, AASHTO, and NEMA and published as the NTCIP 1400-series standards. APTA TCIP claim to have extended the NTCIP standards to include a Concept of Operations, Model Architecture, Dialog Definitions, and a rigorous, modular approach to conformance. Both the APTA TCIP development and the earlier NTCIP development were sponsored by the US DOT Intelligent Transportation Systems (ITS) Joint Program Office. ITE has now officially transferred responsibility for standards in this area to APTA.

On the other hand, the draft recommended practice on security [19] is so high level as to be of very limited value.

An interesting development has been the attempt by APTA to have their standards incorporated in federal regulations, eg, FRA regulations, and even legislation. If the standard meets the business and systems needs of a transportation agency, that's fine and, as discussed earlier, provides some degree of legal protection for the agency. If not, it's likely to cause all kinds of problems. At a minimum, the agency will need to provide a detailed engineering evaluation why the standard does not meet the technical needs of the system or application. Overall, a more cautious approach would be to discourage the blanket incorporation of standards in regulations and legislation, and to instead incorporate standards as needed in technical specifications for suppliers. As noted in [16], there are careful procedures to be followed when referencing standards in specifications.

Electronic payment

Contactless smart cards that do not require physical contact between card and reader are becoming increasingly popular for payment and ticketing applications such as mass transit and highway tolls. Today, unfortunately, most contactless fare collection implementations are custom and incompatible (eg, the CharlieCard used by the MBTA in Boston).

The key open standard for contactless smart cards is ISO/IEC 14443 (types A and B) which allows for RF communications up to 10 cm. On the other hand, ISO/IEC 7816 is the international standard for contact smart cards. ISO/IEC 7816 Parts 4 and above are used by both contact and contactless smart card applications for security operations (ie, encryption and authentication) and commands for interchange.

In Europe, the EMTA (European Metropolitan Transport Authorities) have issued a report on electronic ticketing [20]. The report identifies the advantages of an open standard approach to e-ticketing specifications as "sustainability of systems, modularity of its components, interoperability of systems, provision of information to travelers, cost saving, etc." The primary perceived disadvantage stated was "possible over-costs due to standardization of new equipment." In a competitive marketplace, it would appear highly unlikely that a modular open system would cost more than an equivalent closed system, especially in the long-term when issues of lock-in and switching costs are considered.

A report by the worldwide smart card industry group GlobalPlatform [21] provides similar arguments in favor of open standards solutions for e-ticketing. Their report claims that most Public Transportation Operators are willing to migrate to an interoperable fare management system that relies on open standards.

Finally, the APTA standard for contactless cards has four distinct separable parts dealing with data formats, messages between an agency and a regional system, security (recommendations only and high-level), and criteria for compliance certification and testing. However, the standard does not define the system architecture of the fare collection systems nor the interface between the smart card and the card reader.

8. Summary

There is no reason not to believe that the use of open standards in the transportation industry will not create significant value, from the same perspectives as any other industry.

This can be accomplished by leveraging existing standards in the IT and telecom/network areas, and by building on existing standards, where possible, to meet transportation-specific requirements. The areas where few or no standards exist, notably, rail control and signaling, present the greatest challenge. In such areas, agencies should work together with vendors – as an industry forum or alliance – to develop common specifications which then can be ratified as standards by an appropriate standards organization.

In summary, we have presented in this paper the case for open standards in the transportation industry especially from a business and economic perspective. Having shown that the use of open standards in the telecommunication industry has helped fuel that industry's growth, we have argued that the adoption of open standards in all aspects of the transportation industry – eg, rail control & signaling, IT and electronic payment – will similarly provide significant cost savings as well as developing new revenue opportunities.

References

[1] S. Techapalokul, J.H. Alleman, Y. Chen, "Economics of a standard: a survey and framework," *2nd IEEE Conf. on Standardization & Innovation in Information Technology*, 2001

[2] ANSI history of standards: http://www.ansi.org/consumer_affairs/history_standards.aspx?menuid=5

[3] Ned Harrison, "States Rights doomed Confederate nation," *Free Lance Star*, Fredericksburgh, VA, Nov 12, 2005

[4] Open Source Initiative http://www.opensource.org/osr

[5] Hal Varian, Joseph Farrell, and Carl Shapiro, *The Economics of Information Technology*, Cambridge University Press, 2004

[6] Carl Shapiro and Hal Varian, *Information Rules*, Harvard Business School Press, 1999

[7] George V. Thompson, "Intercompany technical standardization in the early American automobile industry," *Journal of Economic History*, 1954

[8] Thomas L. Friedman, *The World is Flat: A Brief History of the Twenty-First Century,* Farrar, Straus and Giroux; 2005

[9] David Wheeler, "Open Standards and Security," July 2006 http://www.dwheeler.com/essays/open-standards-security.pdf

[10] IEEE 1474.1-2004, "Communications-Based Train Control (CBTC) Performance and Functional Requirements"

[11] IEEE 1474.3™-2008, "Recommended Practice for Communications-Based Train Control (CBTC) System Design and Functional Allocations"

[12] IEEE P1474.4, "Recommended Practice for Functional Testing of a Communications-Based Train Control (CBTC) System" (under development since 2009)

[13] Corinne Braban & Nabil Ghaly, "Modernization of the New York City subway: latest update on the Canarsie Line project," *Proceedings of the 2006 Joint ASME/IEEE Rail Conference*, 2006

[14] IEEE 1473-1999, "An Open-Source Communications Protocol For Railway Vehicles" (Lonworks); Note: IEEE 1473-T is equivalent to the IEC 61375-1.

[15] James H. Dietz, "The new IEEE standards, Guide to using the new generation of IEEE standards for railcar procurements," *IEEE Vehicular Technology Magazine*, Sept 2008

[16] MODTRAIN: http://www.transport-research.info/web/projects/project_details.cfm?id=36249

[17] APTA, Manual of Standards and Recommended Practices for Rail Transit Systems: http://www.aptastandards.com/Standards/Rail/tabid/84/Default.aspx

[18 APTA, Transit Communications Interface Profiles (TCIP) Standard Development Program: http://www.aptatcip.com/

[19] APTA, "Draft Technical Recommended Practice for Securing Control and Communications Systems in Transit Environments: Part 1 - Elements, Organization and Risk Assessment/Management," 2009

[20] Mohamed Mezghani, "Study on electronic ticketing in public transport," EMTA Report, May 2008: http://www.emta.com/IMG/pdf/EMTA-Ticketing.pdf

[21] GlobalPlatform's Value Proposition for the Public Transportation Industry, White Paper, Nov 2009: http://www.globalplatform.org/documents/whitepapers/GP_Value_Proposition_for_Public_Transportation_whitepaper.pdf

List of Acronyms

3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
AASHTO	American Association of State Highway and Transportation Officials
AMPS	Advanced Mobile Phone System
ANSI	American National Standards Institute
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
CBTC	Communications-Based Train Control
CDMA	Code Division Multiple Access
COTS	Commercial off the shelf
DOT	Department of Transportation
ERP	Enterprise Resource Planning
FHSS	Frequency Hopping Spread Spectrum
FRA	Federal Railway Administration
GSM	Global System for Mobile Communications (originally Groupe Spéciale Mobile)
IEC	International Electrotechnical Committee
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Taskforce
IN	Intelligent Network
IP	Internet Protocol
ISO	International Standards Organization
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITU	International Telecommunications Union
LAN	Local Area Network
NEMA	National Electronics Manufacturers Association
OS	Operating System
OSI	Open System Interconnection
OSS	Open Source Software
PSTN	Public Switched Telephone Network
RTVISC	Rail Transit Vehicle Interface Standards Committee
SDH	Synchronous Digital Hierarchy
SDO	Standards Development Organization
SNA	System Network Architecture
SONET	Synchronous Optical Network
TCIP	Transit Communications Interface Profiles
TDMA	Time Division Multiple Access
WLAN	Wireless Local Area Network