Standards Wars

Final Project

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1. What is a standard

"The wonderful thing about standards is that there are so many of them to choose from."
- Grace Hopper

Innovation in computing occurs at a much faster rate than almost any other industry. In addition, the computer market often favors a single winner. As a consequence, most companies either have to set the industry standard, follow it, or risk becoming a footnote in history. This highly competitive environment can result in unintuitive market behavior such as inferior products becoming the standard. In this paper we will explore key themes of technical standards in the field of Computer Science, how these standards are established and how they can be used. The main focus is on standards wars, where two or more competing standards fight for predominance, and we will illustrate tactics and outcomes with four case studies of recent and past standards wars.

When talking of technical standards, the definition of a standard is often not completely clear, and there are various distinctions of standards. For example, a standard can be *de facto* or *de jure*, meaning it is being followed by convenience or because it is enforced by law, and open or proprietary, meaning it is freely usable and documented, or closed. Often, a standard is created by a trusted standards organization such as the International Organization for Standardization (ISO), instead of one single company. Besides that, many would argue that what is often referred to as a standard, is instead a specification or a common procedure. Nevertheless, a standard usually stands for a common definition of a format or an operation, as such giving a benefit to the users of that standard, who can rely on the defined specification. We will use the word "standard" in the broadest meaning possible, distinguishing it further where needed.

2. How are standards established

Standardization process can be driven by standards creators-participants who are motivated to develop new standards or by standards implementers-participants who are motivated to produce new products that embody a standard. They can also be driven by users of standards-who don't usually participate in initial standardization process as they need the openness to address their requirements. They can also be driven by one or more companies that want to dislodge an incumbent player with a competing standard. Some of the common ways to establish standards are:

- **Work with Standards Organizations like ISO, IEEE, IETF, and ITU to get an industry consensus**
  To get a stamp of impartiality many companies prefer going to Standards organizations. For instance the C# language was developed by Microsoft in-house but to compete with Java they went to ISO to standardize the language. That encouraged companies to implement C# for non-Microsoft platforms.

- **Companies band together to challenge competing standard**
  Many times companies share their resources to fight a competing standard. The current standards war between HD-DVD and Blue-ray has group of companies on each side challenging each other.

- **Consortium**
  Many important standards need many companies to formulate them together. Bluetooth is an example of this approach. Here the vendors make money by being on one short-distance wireless standard while competing on manufacturing, service delivery and other features.

- **Ad Hoc/Accidental**
  Many times a technology does not start its life with a quest for becoming a standard. The market-success makes it an accidental standard. DOS for instance became a standard when many companies started building IBM-clones. Once that platform became the most dominant, the OS on it became the market standard.

- **A powerful market player sponsors the technology and gets other companies to adopt it**
  A company with a large market share in a particular industry has an upper hand in introducing new standards. For e.g. in the .Dot Com boom of mid nineties, SUN Microsystems used their dominance in Internet Servers to promote the Java standard.

- **A critical mass of consumers or a very large customer like government can establish a standard**
  One way for a standard to get established is to get a critical mass of consumers to adopt them. VHS and Betamax both were backed by industry consortiums and were "Open" for other partners but VHS won once they overtook in adoption by a critical mass of customers. The requirements of a very large customer like the government can also lead to standards establishment.

- **When a critical mass of key players believe that the standard will be adopted**
  Many times a company has the power to convince the key players that their product will become the standard. For instance the introduction of IBM-PC in 1981

immediately received the support of key market analysts and software vendors as the next computing standard. Hardware manufacturers cloned the architecture as they were convinced in the future of the standard.

3. Importance of Standards

3.1. Componentization

Complexity is one of the main drivers of technology industry standardization. Like in the automobile and aircraft industries, computer solutions are assembled from pre-made components. Without componentization the current rate of progress in the computer industry would be impossible. Standards are critically important to enable componentization by defining common interfaces. For example, ODBC provides a common interface to relational databases. COM+ and CORBA provide a common infrastructure for distributed systems development. Breaking up a complex system into components provides a wealth of benefits. First, components reduce the complexity of the overall system. Second, as components evolve, each company can focus on a specific part. Division of labor lowers cost, improves quality and efficiency. For example, in the PC industry the rate of innovation has significantly increased since the industry has become more horizontally integrated after the advent of PCs. For example, Intel was able to focus entirely on perfecting the microprocessor. Volume and the focus allowed Intel processors to consistently beat those from other vendors. Third, economies of scale can be realized when a company supplies a particular component to the entire market. The sheer number of shipped Intel’s processor drove costs down below IBM and Motorola. Common components can be reused by several applications. That reduces duplicated effort and time to market. All of today’s top supercomputers are built using off the shelf commodity processors and communication network gear. E-Commerce solutions can be built quickly with existing hardware, OS, database and middleware components.

3.2. Impact on Quality

In addition to fostering coordination and efficiency in the market place, standards often help drive quality. Standards compliance often indicates a sufficient level of quality for the product. A well defined standard for an interface reduces integration errors. The specification is often used as a test to verify a particular implementation. In addition to direct impact, some standards, such as ISO 9000 provide a framework and process by which the company can improve their processes.

3.3. Innovation

Standards can accelerate innovation. First, a well defined and agreed upon standard may significantly accelerate adoption of the new technology. For example, DVD was one of the quickest adopted consumer technologies. One of the reasons was the market’s decision to support a single content format. That in turn, encouraged adoption by hardware manufacturers and content providers to actively switch to the new platform. As a result, consumers were confident to buy both new content and the hardware because of the perceived safety of their investment.

3.4. Systems Competition

Platforms expose interfaces upon which a multitude of third-party components and solutions can be built. For example, MS-DOS provides a common interface for third-party software to run on a variety of hardware. Such a platform creates an ecosystem for independent vendors to sell add-ons and customized solutions. Each component by itself has little end-user value. Only together, as a system, do products become useful. For example, a mobile phone can only place a call if there is supporting cellular infrastructure. Computer hardware is a useless without software. The competition of such systems is described in works on Systems Competition. [Katz 1994]. Competition among systems is dependent upon expectations, coordination and compatibility.

For customers to invest into a platform, they must have expectations that it is viable and has a future. Firms working on different pieces must coordinate with each other to ensure compatibility. Standards have very strong effect on this type of competition because it affects all three.

For example, adoption of the GSM standard by a critical mass of European telecom providers ensured massive infrastructure investment. The standard enables independent development of base station equipment, switches, and mobile phones. It also guarantees compatibility of phones across multiple service providers.

4. Standards wars

4.1. What starts them

Standards wars occur primarily because of the nature of the economics at play in industries that have strong network effects which give rise to network externalities. The network effect states that the value of a product or service is a function of the number of people that use that product or service [Liebowitz 94]. A positive network externality exists when the benefits enjoyed by users increase with the addition of more users to the network [SIMS 99]. As a consequence, positive feedback occurs which amplifies the market share of the dominant product or service. With so much at stake, standards wars may be the only option for many companies that wish to dominate a market.

Standards wars can be initiated in many ways and can be intentional or unintentional. Intentional standards wars occur when companies or consortia perceive a competitive threat and preemptively engage in a battle in order to secure their position or influence in the marketplace. This is usually initiated by introducing a new technology in the marketplace that is incompatible with the old technology. This new technology can also be more cost effective or offer better performance than the old technology. Unintentional standards wars can occur when rival companies have good intentions and join standards bodies in order to collaborate on a standard but disagreement becomes the catalyst for a standards war.

4.2. Key assets

In order for a company to win a standards war and dominate a market, a number of assets are helpful and create a strong foundation for later tactics in the battle for predominance. Some of those are described in [Shapiro 1999].

4.2.1. Control over an installed base

A large base of existing users of a standard can guarantee that there will be many adopters of a new standard, provided that it is compatible with the existing one.

An example for that asset is Microsoft and its Windows operating system. An existing user base of Windows will most likely have a large percentage converting to a new version of Windows, as long as it is compatible. Additionally, any standard implemented in Windows that is marketed by Microsoft already has a large number of potential users.

4.2.2. First mover advantage

When being the only option, you will secure a large user base with your standard. Any competing standard will have to catch up with other features to convince the users to convert. If lacking the first-mover advantage, a company can still employ a preemptive tactic to achieve the same effect, as described in the next section. For instance, the audio compression standard MP3 was the first of its kind, which secured a large user base for it.

4.2.3. Reputation

A generally good reputation for the company wanting to bring forward a new standard will help promote that standard, because users trust a company that has earned that good reputation with existing and successful standards or products. Usually, large and established companies can count on that advantage.

4.2.4. Intellectual Property

Existing intellectual property, such as patents and copyright, put a company in a strong position controlling the standard. For one, it ensures that no competitor can simply clone the standard and sell it itself. Besides that, the company can license the usage of its patent portfolio to competitors for royalties, or exchange licenses with competitors mutually.

4.2.5. Killer applications

If applicable, the standard that has the most compelling applications has a clear advantage over competing standards. Often the competitors have similar features and thus the applications don't differ much. But if one standard has a possible killer application the others lack, that is clearly an advantage. As described later in the case studies, the World Wide Web was the killer application that promoted TCP/IP instead of OSI.

4.2.6. Alliances

Companies can gain from existing alliances when promoting a standard. First of all, these allies can be future adopters of the standard. Secondly, they can help develop and promote the standard with division of labor. Because a standard creates a common interface for all, that division is easily possible. The same applies for a division of labor in a large company, the standard as common interface helps in coordination within the company's divisions.

4.2.7. Government support

A standard can be enforced or recommended by a government institution. Because the standard has a legal foundation, a company implementing that standard gains trust from the users. Additionally, if the government supports and uses your standard, you have a secure, long-term base of users. This is happening now with more and more government institutions requiring the usage of the OASIS document format, instead of MS Word.

4.2.8. Strength in Complements

Another key asset is to have a strong market power in goods complementary to the one using the standard. Network effects will guarantee that growing sales for one product will affect the complementary one, also ensuring that the producer has a much higher motivation to promote one of them. This effect can be observed best at Intel: its primary product being processors, it also successfully sells complementary parts like chipsets, wireless cards and graphic chips, for Notebooks marketing all together as "Centrino" [Centrino].

4.2.9. Innovation

A strong ability to innovate, the result of intense Research and Development creates new or better features than the competing standard, or more interesting products to use the standard. This will be a reason for customers to adopt your standard or buy your products, usually paying off the investment costs spent on R&D.

4.2.10. Manufacturing

When having an advantage in manufacturing a firm saves money or is able to produce faster than the competitors. The standard can then be promoted better because the products using it are either cheaper, faster on the market or the firm has more money available for marketing and promoting the product and the standard.

4.3. Tactics employed

In addition to the assets that companies may have in a standards war, they need to employ a number of tactics in order to exploit positive feedback. Shapiro identifies preemption and expectations management as two main tactics for waging a standards war [Shapiro 98], but there are many more tactics such as penetration pricing and compatibility that companies use to their advantage.

4.3.1. Preemption

Being first to market and building a strong early lead over a competing standard is critical to a company's ability to leverage positive feedback. Care must be taken to avoid launching a buggy or less than compelling product just to be first to market. It is important to note that choices regarding an open vs. closed standard and whether or not the standard will be a *de jure* or a *de facto* standard directly affect a company's preemption strategy.

4.3.2. Expectations management

Consumers want to pick the winner and expectations management is the tactic companies use to convince customers that their standard will win. Typically, companies will pre-announce products or product improvements in order to influence consumer buying decisions. Another effective tactic is to form alliances in the hope that a critical mass of influential companies will convince consumers that it is inevitable that the standard those companies are supporting will win over another.

4.3.3. Compatibility with existing standard vs. performance

If a company is going to compete against an existing entrenched technology, they will need to decide if their new technology will be compatible with the existing technology. This is fundamentally a balancing act between the two properties of backward compatibility and performance. In order for an upstart technology to benefit from positive feedback, it must either provide a compelling reason in terms of performance to cause users to switch to their technology or offer an easy migration path to the new technology. The success of the former approach depends on the performance to switching cost ratio and the success of the latter approach depends heavily on how compelling the new technology is over the old.

4.3.4. Open vs. closed standard

Companies that wish to compete with existing standards must also decide if their new technology will be open or proprietary. Pursuing a completely proprietary approach is normally not a good decision when introducing new products. This is because many customers of the existing technology may be reluctant to be locked in to the new technology. If customers do not adopt the new technology then positive feedback can not occur. While an open approach may benefit an upstart company in the short term, in the long run it will limit their share in the market.

For companies that already dominate a market, a closed standards approach is actually a benefit. This is due to the fact that their customers are locked in and, as a result, the company does not have to worry about competitors offering competing compatible products. Despite this obvious advantage, dominant companies sometimes decide to take an open standards approach in order to ensure a rapid adoption of the technology.

4.3.5. *De jure* vs. *de facto* standard

The concepts of *de jure* and *de facto* standards are closely tied to open and closed standards. *De jure* standards are those that have been approved by formal standards bodies such as the Institute of Electrical and Electronics Engineers (IEEE) or ISO. In principle, *de jure* standards are open. Standards that have been created outside the formal standards bodies and have been accepted by a wide audience are called *de facto* standards. *De facto* standards can be open or closed. The OSI model from ISO is an example of a *de jure* standard while the TCP/IP internet protocol is an example of an open *de facto* standard and Windows is an example of a closed *de facto* standard.

For a company that wishes to compete with an existing technology, the choice between a *de jure* standard and a *de facto* standard depends on how open or proprietary their new technology will be. While *de jure* standards benefit from the reputation of the standard body that approves the standard, the process is normally long and cumbersome since agreement must be achieved. Some companies choose to invent the standard themselves in order to achieve the first to market advantage and then obtain formal standards body endorsements and certifications later in order to benefit from the reputation of standards bodies.

4.3.6. Penetration pricing

When a company introducing a competing technology does not benefit from brand recognition and they control little to no market share then they can price their new product or service at a very low price, normally below cost. The rationale for penetration pricing is to quickly gain market share and hence attempt to exploit positive feedback. The disadvantage of this approach is that once you set a price it is difficult to increase the price without alienating users.

4.4. Outcomes

4.4.1. Winner takes all

If network effects are important then the standard may tip the market completely in its favor. For e.g. the mass adoption of VHS forced Betamax completely outside the VCR market. If it is expensive to switch between standards then this "Lock-in" has huge competitive advantages.

4.4.2. Minority persists

In some markets a standard that loses out can still persist for a long time as a significant minority. For e.g. Apple's computing platform has survived as a minority player for over 25 years.

4.4.3. Equilibrium

Some standards wars can result in equilibrium with several standards splitting the market evenly. For e.g. Sony, Nintendo and Microsoft in the US Game Console market.

4.4.4. Standard wins but the company that championed the standard loses

A company may win the industry support for its own technology as a standard but may still lose if its competitors support the standard with even better overall value. For example Java has become a standard but its inventor Sun Microsystems does not dominate in any technology arena today. Bigger vendors devoted even higher R&D budgets for Java and so were able to eventually beat the inventor of Java itself.

4.4.5. Fight to death

Sometimes there are vicious battles among competing standards in which one standard fights until complete defeat. The Direct Current (DC) standard's loss against AC (Alternating Current) is one such example.

4.4.6. Multiple standards co-exist

Multiple standards can co-exist if they do not lock each other out and they interoperate with each other. For e.g. the various standards for cellular telephony- GSM, CDMA etc. If some standards are highly entrenched then the newer competing standards co-exist with them and actually expand the market. For e.g. Mainframes style servers co-exist with the Unix/Windows based Servers.

4.4.7. End in a cease-fire

The market may start with many competing standards but eventually a common standard gets adopted. For e.g. the 56K modem standards war between X2 and K56Flex standards was eventually solved with the V.90 standard by ITU.

5. Case Studies

After the background information about standards and wars in between them, we will now illustrate our points with four case studies of recent or past standards wars. We think they pose interesting examples of how the available assets can be used together with some of the tactics to fight a standard war, and what outcomes one can expect.

5.1. MP3 vs. Ogg Vorbis vs. WMA

5.1.1. Introduction

As more and more people like to enjoy digital music on their way, digital audio players are becoming increasingly ubiquitous [Instat]. The common players are all either Flash-memory or hard disk based. But all of them play music from audio files, just like personal computers. These files contain digital music, usually compressed with a lossy audio compression format.

The most common format is MPEG-1 Audio Layer 3, usually referred to as MP3, and in use for more than a decade already. MP3 was developed at the Fraunhofer Institute for Integrated Circuits (IIS) in Germany. Preparing work was finished in 1989, and MPEG-1 Audio Layer 3 was established as ISO/IEC standard in 1992 [Fraunhofer]. The first software player was released in 1995.

As a reaction to the Fraunhofer Society announcing to charge fees for the usage of the patents covering the MP3 technology, in 1998 the development of the audio codec (short for Compressor-Decompressor) Vorbis began, aimed to "[...] completely replace all proprietary, patented audio formats" [Xiph, MP3Tech, Slashdot] . Usually, audio compressed with Vorbis is stored in the container format OGG, which was developed simultaneously. So precisely, the audio file is called Ogg Vorbis but is often referred to as "OGG". The project was founded by Christopher Montgomery and developed as a typical Open-Source project, finishing major development with version 1.0 in 2002.

Also competing with MP3 is the proprietary audio format by Microsoft, Windows Media Audio (WMA). In the beginning, WMA was aimed to compete with MP3 too, and to avoid the licensing fees associated to MP3. Now it is pushed forward by Microsoft to be used as standard audio codec for music on the Windows PC, in digital audio players and for sound in movies. WMA, together with the Video Codec WMV, is integrated in the Windows Media Framework, and there are a number of versions available [MS:WMA].

Advance Audio Coding (AAC) is another main format which is established as global standard, even though it is currently used mainly by Apple in their iTunes store and on the iPod [Apple:AAC], encapsulated in a file with extension .M4A. With that, it gained popularity just recently, but we will cover it only briefly, mainly focusing on the "war" between OGG, WMA and MP3.

5.1.2. Key Assets

5.1.2.1. First-mover advantage

In the 90's, no efficient audio compression algorithm existed. So, clearly, the Fraunhofer Society had the first-mover advantage on its side when developing the MP3 codec. With the growing use of the Internet and personal computers being used more and more as multimedia devices, users adopted the audio compression standard quickly and created collections of music stored in the MP3 format, by either converting their tracks from CDs or sharing files over the Internet. MP3 made both of it possible, by drastically reducing the file size at about a ration of 10:1 without a noticeable large loss of quality (using a psychoacoustic model): Back then, both space on hard drive and bandwidth was very limited compared to today.

5.1.2.2. Innovation

Initially, MP3's level of innovation was extremely high, there was no comparable way of compressing audio at that ratio and quality. But since then the quality of encoders in the standard MP3 format has not changed much, leaving room for competing standards to challenge it. That is what Microsoft tried with WMA, and what OGG is aiming at. Independent listening test at comparable file sizes acclaim standard WMA a worse quality than MP3, with OGG clearly in the lead [Hansen 2002, Amorim].

5.1.2.3. Intellectual Property

Additionally, the algorithms for encoding audio in the MP3 format are covered by patents of the Fraunhofer Society and Thomson, with licensing being done by the latter [MP3licensing]. This keeps competitors from copying the technology and creates income. A side effect was, however, the development of the competing standards WMA and OGG to avoid licensing costs to Thomson, with the latter being completely free and without restrictions.

5.1.2.4. Strength in complements and reputation

Of the three covered audio formats, only WMA can benefit from indirect assets of its creator, Microsoft. The wide spread of the operating system Windows provides both a generally good reputation among consumers and a large installation base for the WMA codec. The same effect could be observed in the bundling of Internet Explorer and Windows. Neither OGG nor MP3 have similar assets, with OGG being a project founded by the Open source community, and the Fraunhofer Institute for Integrated Circuits as a research institution having been quite unknown among consumers prior to the development of MP3.

Furthermore, the huge company Microsoft can draw on large resources for development and propagation of WMA as an audio standard. For example, their new Audioplayer "Zune" together with a digital music store could spread WMA even more, just like the previously seldom used format AAC was promoted by Apple.

5.1.3. Tactics

5.1.3.1. No preemptive tactics

One might think that the Fraunhofer IIS was using preemptive tactics to conquer the market, but since there was virtually no competition when the development of MP3 was done, there was no need to actively force it on the market, the first-mover-advantage was already favoring MP3.

5.1.3.2. Expectation management

In contrary, Microsoft used expectation management marketing to advertise WMA as superior to MP3, even providing a listening test that is no longer available. As discussed above, independent listening tests accredited WMA a worse quality than MP3, with OGG even superior.

5.1.3.3. Pricing

Because the initial reason for Microsoft to develop WMA was to avoid licensing issues, using that standard in Windows or other Microsoft products is of course free for Microsoft. However, any other manufacturer of audio hardware or software has to pay licensing fees to Microsoft when supporting WMA [MS:WMAlicensing]. The same applies for MP3, even though the fees for licensing have to be "Reasonable and non-discriminatory", as demanded by the ISO for establishment of a standard [ISO]. OGG, in contrary, is completely free of any fees, and this is used to promote it. This tactic is actually working only partially: by now, a large number of computer games use the format for sound effects and music to save licensing fees, among it popular games like Unreal Tournament, Quake 4 or FarCry. But since the end-user never gets in touch with licensing fees for distributors, and players for all sound formats, like WinAmp, Windows Media Player or XMMS are available for free, licensing fees hardly affect the end-user. Similarly, the manufacturers of digital audio players don't gain much, because they have to support WMA and MP3 for the majority of existing files anyways - still, companies like iRiver or Cowon support playing OGG files on their players. But supporting OGG creates only additional costs for implementation, even if there are no licensing fees. This explains the low distribution of OGG at the side of the home users.

5.1.3.4. *De facto* vs. *de jure* standard

Of the three covered standards, so far only MP3 is established as *de jure* standard. From the start on, it was registered at ISO and International Electrotechnical Commission (IEC). The funds available to the Fraunhofer Society allowed that, and the establishment as an ISO/IEC standard encouraged the adoption of MP3 because it ensured that all programs coding or decoding audio in the format were compatible. OGG, however, only aims to become a *de facto* standard. An open source project relying on donations just doesn't have the funds to go through the long and expensive steps of becoming an ISO standard. Of course, there are open source standards like the Open Document Format that get established at the ISO, but usually there are a number of large, paying companies supporting it form the start. Quite contrary, Microsoft did not establish WMA as a *de jure* standard, but the usage in the popular Windows operating system is clearly enough to regard it now as an established *de facto* standard. Comparing this to OGG and MP3, the conclusion is that it is not necessary for a standard to be *de jure* to compete in a standard war. As long as other tactics ensure the wide adoption, a standard becomes *de facto*.

It is worth noting, however, that OGG has been submitted as RFC 3533 and 3534 in May 2003, forming a more serious foundation for it as a standard [RCF]. Microsoft is following similar paths by submitting VC-1 as SMPTE standard, which uses Windows Media Video and Audio [MS:VC-1]. With that, the established *de facto* standard will be turned into a *de jure* standard.

5.1.3.5. Open vs. closed standard

How does the design as open or closed standard affect the outcome of the competition? The three covered standards here are all different in that respect: WMA is a proprietary standard and closed as such. MP3 is open despite being patented, which is not mutually exclusive. OGG represents the most open standard: It is documented, free to use and the source code is available. The openness of MP3 was surely one factor that led to its fast proliferation. As WMA shows, however, it is not required, because Microsoft can draw on other resources like marketing power.

5.1.3.6. Compatibility

Neither one of the standards is in some way compatible to each other. All compression algorithms covered here work slightly different and are lossy. That means that converting from one to another will always degrade sound quality. However, later extensions to WMA and MP3, such as mp3pro are backwards compatible. That way, a transition to the designated successor standard can be made without losing the current user base.

This incompatibility between the standards practically leads to a lock-in of users who have existing music collections encoded in one format. If someone wanted to convert to using OGG for their digital music collection, they would either have to convert every existing file, which takes some time and degrades sound quality, or re-collect the music either by buying the music files in the new format or transcoding them again from a CD, which might not be available anymore.

5.1.4. Outcome and the future

So far, the first-mover advantage and the initial level of innovation, combined with the lock-in was enough for MP3 to set an enormous lead. Neither WMA nor OGG were able to challenge that lead, even though Microsoft was able to market WMA well enough to become the second most-used compression format. Still, for OGG niches exist, as mentioned above. Due to the nature of files that can be bought or transcoded by hand, it is hard to measure a "market share" of the standards, but a survey in 2004 showed that 72% of music files on hard drives are MP3, 19.6% WMA, AAC 4.3% and other, among them OGG, only 3.9% [cnet].

For the future, Microsoft with WMA could possibly claim a larger part of the "market share" of MP3 because of Zune and its music store. To turn OGG into a success for the users, the advantages by quality and availability as Open source have to be promoted further to the end-users. In any case, all competitors must hurry until 2010, because then one of the current disadvantages of MP3 will disappear: The patents for MP3 were filed in 1996 as "design patents", that means that they will expire after 14 years.

So concluding this case study, being the first on the market with a high innovation and the competitors not being advantageous enough is sufficient to dominate the market for a long time. And at the moment, it doesn't look like MP3 is going to disappear any time soon.

5.2. SIP vs. H.323

5.2.1. Introduction

There are two signaling standards that are competing in the young and dynamic field of IP telephony, where many solutions are still under review and debate.

- H.323, the ITU's (International Telecommunication Union) umbrella standard for audio, video and data-sharing over packet (IP) networks, is already widely deployed and has significant market share.
- SIP, the IETF's multimedia signaling protocol, is gathering attention for its simplicity and modularity.

All the major players including Cisco and Microsoft are moving to SIP for most of their future telephony products. So how did the latecomer SIP technology win over the well entrenched incumbent H.323? The biggest advantage SIP has that it’s a great fit for the Internet and World Wide Web. With the world going to one network for data and audio communication, a HTTP like signaling protocol (SIP) has a distinct advantage over H.323 which is based on ITU's network model. SIP can integrate easily with other communication and Web services and utilizes the standard Internet protocols for security and scalability.

5.2.2. Key Assets

5.2.2.1. No First Mover Advantage

H.323, the ITU's umbrella standard for audio, video and data-sharing over packet (IP) networks, was already widely deployed and had significant market share. But SIP, the IETF's multimedia signaling protocol, is gaining market share because of its simplicity and modularity. [VoiceCon-2003]

5.2.2.2. The new standard offers a revolutionary change

SIP differs from H.323 at a fundamental level: in SIP, the "intelligence" is distributed among the clients (i.e., their computers) in a more distributed architecture, as opposed to the H.323 model of an intelligent central coordinating site surrounded by "dumb" terminals

5.2.2.3. Complexity vs. Simplicity

H.323 is not a single protocol but rather an entire suite of protocols that cover everything in one vertically integrated stack. For a mature technology this may not be a problem, since the best solutions are likely to have been discovered and incorporated into standards. However for the young field of IP telephony, flexibility is more important. SIP is part of this flexible approach, as it uses a wide variety of protocols, each addressing a different aspect of the problem space. The advantage is the ability to choose from among many competing technologies and move to newer and better ones as they emerge. This has always been the philosophy behind SIP and this is the approach of the IETF to IP telephony in general.

5.2.2.4. Developer buy-in

SIP is a simple Request-Response protocol where all the commands on the network flow in plain text like HTTP and SMTP. This has resulted in a huge adoption by the developer community. A quick search at SourceForge on Dec/4/2006 yields over 120 projects using SIP whereas H.323 has less than 30 projects. All the network traffic in H.323 is in binary and that makes the development cryptic and expensive to debug. SIP has been able ride on the huge popularity of web related development with which it is perfectly compatible. With SIP, the media itself is independent of the signaling protocol. As a result, SIP can be used to set up a voice or video call as well as set up a gaming or instant messaging session. In other words, SIP is not just a VoIP protocol. SIP is usable in so many areas, that developers will continue to become more familiar and get more creative with SIP than they will with H.323. This network effect of applications with SIP portends well for the protocol.

5.2.2.5. Platform for innovation

For a protocol to become a standard it has to enable fast innovation. H.323 is not favorable to innovation as developers don't get quick access to central control units or change interface standards in a timely fashion. SIP whereas is a classic Internet-centric technology. It relies on protocols rather than an API which can become vendor or OS specific.

5.2.3. Conclusion

SIP as an open-standard, device-independent and flexible protocol. We are expecting SIP to continue increasing its market share and supplant H.323 for Voice communication over the Internet.

5.3. TCP/IP vs. OSI

5.3.1. Introduction

During the 1980's and early 1990's ISO introduced and championed the Open System Interconnection (OSI) architecture as a more open and robust solution than existing experimental networking protocols such as TCP/IP. At stake was not only what would become the standard networking protocol of the Internet but which two completely opposite standardization processes was best equipped to develop standards for the fast evolving field of networking.

5.3.2. Key Assets

The key assets in this standards war include who had the first mover advantage, alliances, and who had government support. Intellectual property was a non issue since both standards were open and non-proprietary.

5.3.2.1. First-mover advantage

TCP was first introduced in 1973 by Robert Kahn and Vint Cerf and in 1978 it was split into the current form of two separate protocols TCP/IP by Cerf and other researchers at DARPA. Five years later in 1983, TCP/IP was made the standard host networking protocol for the Arpanet [IEEE COMSEC 2002]. TCP/IP was not just a specification, actual running code existed. Moreover, those that implemented TCP/IP actually wrote the specification. In contrast, in 1977 ISO setup a committee to begin meeting on what would become the OSI model which finally became an international standard in 1983. TCP/IP's first mover advantage was multiplied by the fact that it was widely implemented and it worked. OSI, on the other hand, was an international standard developed by committee and consisted of a theoretical specification and no implementation. This first mover advantage allowed TCP/IP to enjoy a significant user base and thus leverage positive feedback.

5.3.2.2. Government support

OSI enjoyed support from many governments such as members of the European Commission and Japan. For these governments, the rationale for supporting OSI over TCP/IP stems from the fact that TCP/IP was a product of U.S. government research. By joining the ISO standardization process, these governments could ensure that their national interests could be protected. Surprisingly, the U.S. government also pledged it support for OSI. In 1985, the U.S. Department of Defense, which had funded the research that produced TCP/IP, decided to eventually move to OSI. Three years later the National Bureau of Standards mandated that by 1990, all federal agencies must procure products compliant with a derivative work of OSI called GOSIP. Government support was clearly on the side of OSI and many people believed that TCP/IP would be replaced when the Department of Defense announced that they were going to switch to OSI.

5.3.2.3. Alliances

Despite the fact that TCP/IP was actually being used in practice and OSI was merely a specification, many companies pledged full support for OSI. This was the result of many governments aligning themselves with OSI. While some of these companies did form alliances, the benefits from division of labor could not overcome the inherent difficulty in developing products from the OSI specification. This is because the OSI specification was developed by committee and valued formal specification over feasibility of implementation.

5.3.3. Tactics

Both standards were open and non-proprietary in addition to being incompatible. Moreover, TCP/IP existed before ISO even began working on OSI thus a preemption strategy was not applicable. Therefore the tactics employed included expectations management as well as the type of standardization process utilized.

5.3.3.1. Expectations management

Since the OSI specification was so far behind TCP/IP, the proponents of OSI waged a full fledged expectations management offensive. ISO was able to gather critical governmental support and also leveraged its reputation as a formal standards body to promote OSI. Manufacturers were convinced that they should announce their commitment to developing OSI compliant products. Proponents on the TCP/IP side also employed expectations management in the form of publishing critiques of OSI in a number of scholarly and technical journals.

5.3.3.2. *De jure* vs. *de facto* standard

TCP/IP was developed and refined by government, academic, and industry researchers outside the official standards setting bodies. Once it was widely adopted, it became a *de facto* standard. In contrast, the OSI specification was developed by representatives from national governments under the auspices of ISO. When the OSI specification was published in 1983 it became *de jure* standard.

The developers and maintainers of TCP/IP recognized from the start that networking was a volatile field which required a flexible process by which protocols could be agreed upon and implemented. The process started with the Internet Configuration Control Board (ICCB) and was eventually managed by the Internet Engineering Task Force (IETF), both encouraged open participation and a decentralized division of labor. At the July 1992 IETF meeting, David Clark famously summed up this process when he said, "We reject: kings, presidents, and voting. We believe in: rough consensus and running code." [Clark 92]. This focus on "rough consensus and running code" ensured that TCP/IP did not suffer from the delays that plagued *de jure* standards such as OSI which required agreement and multiple compromises just to become a theoretical standard.

To the designers of OSI, what mattered most was protecting their respective national interests. Since TCP/IP already existed, the only way to achieve this was through an official standards setting process. Time to market and feasibility of implementation were almost of no concern. Historically, this approach had worked before in telephony markets. Unfortunately, the participants of the OSI standardization process did not understand that the evolving computer networks were unlike anything that had preceded them. Due to the slow progress inherent in formal standardization work, the OSI standardization process simply could not keep up with the rapid change of technology.

5.3.4. Outcome

Although OSI had the support of academics and many governments, ultimately it became clear that the rigid standards body based approach could not keep up with the rapid change of networking technology. TCP/IP had been developed in a more informal and nimble standards creation process which was ideally suited for Internet based standards work. The Internet specifications themselves where written for implementers and source code was freely available. Participation in OSI cost substantial money and even the published specifications were not free. Worse yet, the OSI specification contained no source code and ease of implementation was not a priority of the specification. TCP/IP enjoyed a significant first mover advantage and could leverage positive feedback to its advantage. However, it is probably the introduction of a killer application called the World Wide Web - which sits on top of TCP/IP - that hastened the demise of the OSI model and resulted in TCP/IP becoming the dominant networking protocol of the Internet. TCP/IP's ability to clearly gain the first mover advantage and avoid being mired in delays common in official standards setting bodies showed that the open participation and a decentralized division of labor approach championed by ICCB/IETF was best equipped for Internet based standards work.

5.4. Apple Macintosh vs. IBM-Compatible PC

5.4.1. Introduction

Rise of the personal computer has been the most important event in the computer history of the last quarter of a century. One of the more interesting chapters has been the competition between two platforms, IBM-compatibles (Wintel) and the Macintosh. Wintel ended up clear winner with over 1.5 billion units sold from its release in 1981. [C-I-A]

5.4.2. Key assets

Apple’s first runaway hit was the 8-bit Apple II computer released almost 5 years before IBM PC. However it lacked certain features that limited its appeal to business customers. As soon as IBM announced the release of the new 16 bit personal computer, it was viewed as a serious business machine with strong backing of the industry leader. Contemporary analysts correctly predicted the eventual dominance of IBM PCs for the following reasons: [Isaacson, Juliussen 1981]

- Support by the current industry leader, IBM
- Support of the industry software standards

- Strong third party hardware and software support
- Independent Distribution Channel
- Technical superiority and price (16 bit, Color, expansion slots)

Apple responded three years later in 1984 with this release of the Macintosh. The new computer leap-frogged the IBM in terms of the graphical user interface. The quality of the interface was not matched on an IBM machine for almost 11 years. Despite its lead, Apple was lagging behind Wintel in many other key innovations:

Innovation	IBM Compatible	Macintosh	Mac lead/Lag
16-bit computer	1981 (IBM PC)	1984 (Macintosh 128)	-3 years
Color computer	1981 (IBM PC)	1987 (Macintosh II)	-6 years
Expansion slots	1981 (IBM PC)	1987 (Macintosh II)	-6 years
Portable PC	1982 (Compaq)	1989 (Macintosh Portable)	-7 years
Hard disk	1983 (IBM XT)	1986 (Macintosh Plus)	-3 years
Laptop PC	1984 (HP-110)	1991 (PowerBook)	-7 years
Graphical user interface	1990-1995 (Windows 3.0, 95)	1984 (Macintosh 128)	+6 to +11 years
Mouse	1985 (Microsoft Mouse)	1984 (Macintosh 128)	+1 years
RISC-based CPU	(none)	1994 (Power Macintosh)	N/A
First server OS	1993 (Windows NT)	1999 (OS X Server)	-6 years

5.4.2.1. First Mover advantage

By the time Macintosh was introduced, Wintel computers already had a large installed base. Macintosh was not backwards compatible with Apple II and was not able to take advantage its large install base. Over time IBM kept gaining market share. By around 1990 the share of Macintosh had dropped to 7.4% and by 2000 to only 2.8% percent [Joel West 2002]. Throughout the years Microsoft has ensured backwards compatibility for majority of the software. For example, Windows XP released in 2001 supported the 1983 version of MultiPlan.

5.4.2.2. Reputation

One of the key reasons for the rapid adoption of IBM PC was IBM. As an unchallenged leader for over 30 years it commanded respect. IBM had strong business credentials that helped it sell the computers to the enterprise. It also had the leverage over computer industry to ensure third party support.

Macintosh GUI interface was revolutionary at the time of its release. However, the computer came out with very few business applications and was looked at as a toy by the business customers. The situation changed when Microsoft released the first GUI application – Office for Macintosh. Important software for Macintosh came from Adobe and Aldus: Photoshop, PageMaker, and Postscript. Those programs established Mac's dominance in the creative and publishing industries. However, Macintosh could not match the sheer numbers of titles available for PCs. Wintel computers had killer applications for pretty much all the other PC markets. Over 80% of software titles released for personal computers were only available on PCs in the 1990s.

5.4.2.3. Developer by-in

Microsoft understood early the importance of independent developers in the success of Windows platform. The company invested heavily in developer tools such as Visual Studio, established developer support programs such as MSDN (Microsoft Developer Network), supplied key partners with Betas of their products. In addition, the dominating market share promised high return for developers. On the other hand, Apple's record with developers has been spotty. On several occasions, the company treated their partners poorly. For example, on one occasion Apple abandoned Adobe's PostScript in favor of TTF (True Type Fonts) as its font technology to avoid paying royalties. On another occasion, Apple failed to invest in developer tools for the new PowerMac. Only a heroic effort by MetroWerks to ship CodeWarrior in time saved the company during the transition to the new RISC chip. [Carlton 1997]

5.4.2.4. Partnerships

Like IBM and DEC, Apple has been a vertically integrated company throughout its history. It produced its own hardware and software. Its natural allies were their users, third party developers, and processor manufacturers. Apple has switched its processor alliances three times from Motorola to IBM (PowerPC) to Intel. On the other hand PC industry was comprised of several key players each providing a piece of the puzzle. Alliance and cooperation between players have been very important. Intel and Microsoft were one of the strongest allies that worked together to ensure compatibility. Microsoft also relied on multitude of hardware OEMs to distribute its software by bundling it with their hardware. Microsoft also partnered with many independent solutions providers to create vertical applications. A MCSE (Microsoft Certified Systems Engineer) program was established to increase ranks of IT professionals to promote its own products. Clone manufacturers specialized on cranking out the ever cheaper hardware.

Key advantage of the Wintel platform was its horizontal integration. Different companies were able to focus on different aspects of computing solutions. Intel and AMD were creating processors, Microsoft, Operating system and key applications. Dell and Compaq were providing cheap hardware. Independent consultants and IT professionals provided custom solutions based on the platform. Third-party vendors provided value added applications. In contrast Apple was responsible for most of the same functions and it found itself at disadvantage.

5.4.2.5. Innovation

Apple has a strong reputation as an innovation engine. While this is particularly true for several breakthrough products such as GUI, Music players and the design of the hardware, it fell behind between 1985 and 1995. After almost 11 years of lead time, Macintosh innovation has slowed enough for Windows to catch up and achieve feature parity for its GUI.

5.4.3. Tactics and Outcome

From the beginning, IBM has created the PC as an open standard. It encouraged the third party vendors to create compatible extensions and even clones, as long as they paid the license for the only proprietary piece of software, the BIOS. After several years, other companies were able to sidestep the intellectual property restriction by developing their own compatible versions of BIOS using "clean room" techniques. [Ceruzzi 2003] That opened the floodgates of competition that drove the price of hardware down. The competition got so intense that even IBM was left with only 11.9% of the market by 1990. In 2003 it left the market altogether by selling its PC division to Lenovo. The operating system was also open, but pretty soon MS-DOS became the clear winner since it was shipped with all the new machines by default.

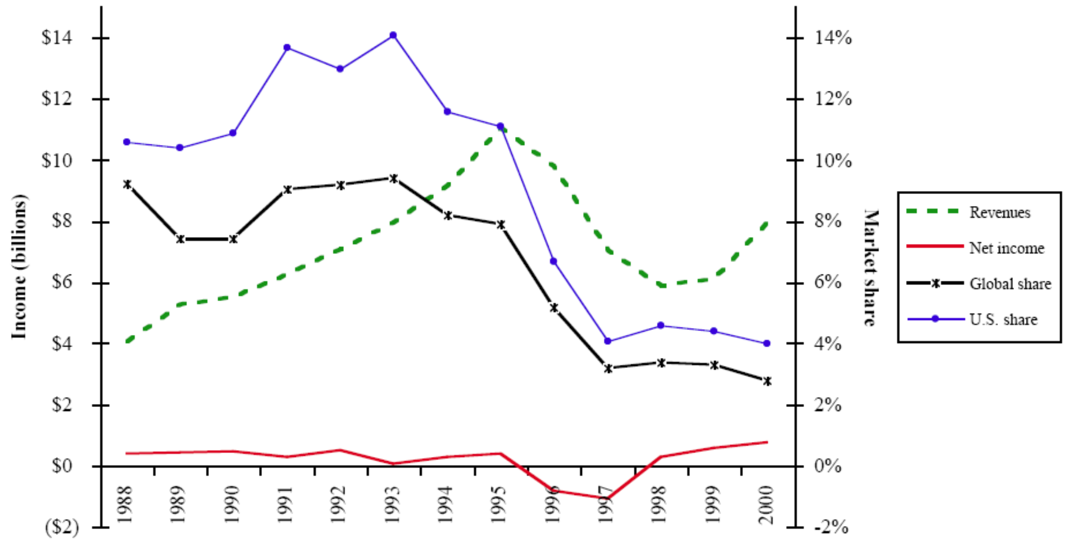
To overcome the advantage of the entrenched market leader Macintosh used marketing and technical innovation. The release of Macintosh was heralded by one of the most memorable advertisements of all time – the famous Super bowl 1984 commercial. The marketing was brilliant and it helped create the excitement about the new platform. Macintosh faced an uphill battle against the large install base of the IBM computers. One of the ways to overcome the challenge was to open the Mac standard and license it to third parties. As Bill Gates proposed in the secret memo to Sculley in 1985: [Carlton 1997a: 40-41]

"As the independent investment in "standard" architectures grows, so does the momentum for that architecture. The industry has reached the point where it is now impossible for Apple to create a standard of their innovative technology without support from, and the resulting credibility of, other personal computer manufacturers"

Overall there were seven occasions when the company considered licensing its technology. The table below lists different attempts: [Joel West 2004]

Date / Firm	Status	Reason Apple Killed It
1985 Microsoft	Proposal by Bill Gates	Unknown
1987 Apollo	Contract signed by Apollo	CEO (Sculley) changed his mind
1987 Sony, Tandy	Requested license to GUI	Unknown
1990 Sun Merger	approved by management	Dropped when Apple adopted IBM PowerPC
1992 Intel, Novell	Working prototype of Mac OS on Intel hardware	Product champion left company
1994-1997 Power Computing, Pioneer, Motorola, others Nearly 500,000 computers sold based on PowerPC chips	Nearly 500,000 computers sold based on PowerPC chips	Canceled by new CEO (Jobs)
1995 Gateway 2000	Contracts ready for signature	Opposition from Apple sales executives

Apple never succeeded in licensing its technology. Instead it chose a “high-right” approach of a differentiated premium product that commanded a premium price. Despite constantly lowering market share, the company remained profitable until the release of Windows 95 erased the perceived technical superiority of the Mac. See the chart below:



Source: Company annual reports; Dataquest
Note: Revenues and net income for fiscal year ending September 30; market share is calendar year

Figure1: Apple financial performance, 1988-2000

Graphics credits: [Joel West 2004]

Unlike Windows, Macintosh could not afford to make their platform completely backwards compatible. One justification for that was that a company with a small share has little to lose, but a lot to gain. The decline of Apple in the 90s has often been compared to the fall of the BetaMax videocassette standard. The theory of network externalities would predict that a single player would emerge victorious and the looser market share would drop to zero because of positive feedback and Network externalities [Farrell & Saloner 1986; Arthur 1989, 1996; Katz & Shapiro 1994; Shapiro and Varian 1999]. Despite a few close calls, Apple platform remained viable and even began gaining market share in the last several years. That phenomenon would contradict the theory of the tipping markets. Several authors including Joel West have suggested that incompetence and mismanagement played the leading role in the downturn of the Apple [West 2004]. Specifically, he mentions errors in product strategy execution, poor inventory management bad product planning and execution. Bill Gates supported this view:

"Business professors love to talk about strategy, and as Apple has declined, the basic criticism seems to be that Apple’s strategy of doing a unique hardware/software combination was doomed to fail. I disagree. Like all strategies, this one fails if you execute poorly. But the strategy can work if Apple picks its markets and renews the innovation in the Macintosh [Schlender 1996]."

Recent resurgence of Apple after improved leadership of returned Steve Jobs gives merit to this idea. Joel West then goes on to suggest that a better analogy then the BetaMax might be BMW. The car company commands only 11% of the market, yet enjoys stable and profitable existence.

6. Conclusion

The economics of technological competition make winning a standard war critical to survival. As our case studies have shown, several factors determine which standard will prevail. Examples of TCP/IP and MP3 demonstrate that it is critically important to build the early momentum by being first to market with the working solution. However, when the technology is at an inflection point, opportunity exists for the new player to overrun an established standard: The emergence of the Internet helped SIP to establish dominance in the VoIP market and the early mover H.323 has been displaced because it failed to take advantage of the Internet. Apple is an example of how the quality of management and execution can either exacerbate or overcome network effects in a tipping market. Government support also does not guarantee winning the standards war. As the examples of H.323 or OSI show, other assets or tactics could have more impact.

The upcoming years promise to have even more bitter standards wars as the proponents learn from previous experiences. HD-DVD vs. Blue-ray Disc is going to be the most important standards war in the year 2007. We intend to watch it closely to see what tactics and assets will be utilized for winning it.

References

Web Pages

[Amorim] Amorim, Roberto (23rd May, 2004). *Results of Multiformat at 128kbps public Listening Test*, viewed December 3rd 2006.
http://rjamorim.soniccompression.com/test/multiformat128/results.html

[Apple:AAC] Apple *QuickTime Technologies - AAC Audio*, viewed December 3rd 2006
http://www.apple.com/quicktime/technologies/aac/

[Centrino] Intel Corporation *Intel® Centrino® Mobile Technology Product Information - Overview*, viewed December 2nd 2006.
http://www.intel.com/products/centrino/index.htm

[C-I-A] *25-Year PC Anniversary Statistics*
Computer Industry Almanac
http://www.c-i-a.com/pr0806.htm

[cnet] John Borland (October 15th 2004), CNet *MP3 losing steam?*
http://news.com.com/MP3+losing+steam/2100-1027_3-5409604.html

[Fraunhofer] Fraunhofer Society *Fraunhofer IIS Audio & Multimedia Realtime Systems*, viewed December 1st 2006.
http://www.iis.fraunhofer.de/amm/projects/mp3/index.html

[IEEE COMSEC] *IEEE Communications Society - 50th Anniversary, 1952-2002*, viewed December 2nd, 2006
http://www.ieee.org/web/aboutus/history_center/conferences/comsoc/chapter4.html

[Instat] Instat (May 1st 2006) *MP3 Player Market to Reach 286 Million Units by 2010*, viewed December 3rd 2006
http://www.webwire.com/ViewPressRel.asp?aId=13399

[ISO] International Organization of Standardization (August 2nd, 2006). *ISO standards and patents*, viewed December 3rd 2006.
http://www.iso.org/patents

[Liebowitz 1994] Liebowitz, S. J. and Margolis, Stephen E. (1994). *"Network Externalities (Effects)"*
http://wwwpub.utdallas.edu/~liebowit/palgrave/network.html

[MP3licensing] Thomson. *mp3licensing.com - Patents*, viewed December 1st 2006.
http://www.mp3licensing.com/patents/index.html

[MP3tech] MP3 tech (2002) *Patents and MP3*, viewed December 1st 2006
http://www.mp3-tech.org/patents.html

[MS:VC-1] Microsoft Corporation. *What Is VC-1?*, viewed December 1st 2006.
http://www.microsoft.com/windows/windowsmedia/forpros/events/NAB2005/VC-1.aspx

[MS:WMA licensing] Microsoft Corporation. *Windows Media Licensing Fees and Royalties*, last viewed December 3rd 2006.
http://www.microsoft.com/windows/windowsmedia/licensing/licensing.aspx

[MS:WMA] Microsoft Corporation. *Windows Media Audio Codec*, viewed December 1st 2006.
http://www.microsoft.com/windows/windowsmedia/forpros/codecs/audio.aspx

[SIMS 1999] School of Information Management and Systems, University of California Berkeley (June 1999). *Network Economics*.
http://www2.sims.berkeley.edu/resources/infoecon/Networks.html#extern

[Slashdot] (Aug 14 2000) "emmett" on Slashdot *Ogg Vorbis - The Free Alternative To MP3* Interview with Christopher Montgomery about the development of Ogg Vorbis, viewed December 1st 2006.
http://features.slashdot.org/article.pl?sid=00/08/14/1034209

[VoiceCon-2003] Sneeringer, James (Feb, 2003). *VoiceCon 2003*, viewed December 2nd 2006.
http://www.wave-report.com/conference_reports/2003/VoiceCon2003.htm

[Xiph] Xiph.Org (October 3rd, 2003) *Vorbis.com: FAQ*, viewed December 1st 2006.
http://www.vorbis.com/faq/

Articles

[Hansen 2002] Sven Hansen (September 9th 2002). "MP3-Nachfolger im c´t-Hörtest." *c't magazin für computertechnik*, Vol. 19/02, pp.94ff
Heise Verlag.
http://www.heise.de/ct/02/19/094/default.shtml

[Katz, Shapiro 1994] Michael L. Katz, Carl Shapiro (Spring, 1994). Systems Competition and Network Effects. *Journal of Economic Perspectives*, Vol. 8, No. 2, pp. 93-115
http://wwwpub.utdallas.edu/~liebowit/knowledge_goods/k&sjel94/jel94.html

[RFC] L. Walleij (May 2003). *The application/ogg Media Type*
RFC 3534
http://www.ietf.org/rfc/rfc3534.txt

[Isaacson, Juliussen 1981] Dr. Portia Isaacson and Dr. Egil Juliussen (1981). *IBM'S Billion Dollar Baby: The Personal Computer*.
http://www.futurecomputing.com/All/pubs/IBMs%20Billion%20Dollar%20Baby.pdf

[Russell 2006] Russell, Andrew. (2006). 'Rough Consensus and Running Code' and the Internet-OSI Standards War. [Electronic version].
IEEE Annals of the History of Computing, Volume: 28, Issue: 3. pp 48-61.

[Schendler 1996] Schlender, Brent (1996). Paradise lost: Apple's quest for life after death. *Fortune* 133 (3), Feb. 19, 64.

[West 1999] West, Joel (1999). Reconsidering the Assumptions for 'Tipping' in Network Markets. *Proceedings of the 1st IEEE Conference on Standardisation and Innovation in Information Technology,* Aachen, Germany, September, 163-167.

[West 2004] West, Joel Ph.D. (2004). The fall of a Silicon Valley icon: Was Apple really Betamax redux?
http://www.cob.sjsu.edu/west_j/Papers/West2004a.pdf

Books

[Carlton 1997a] Carlton, Jim (1997a). *Apple: The Inside Story of Intrigue, Egomania, and Business Blunders.*
New York: Times Business.

[Ceruzzi 2003] Paul E. Ceruzzi (2003). *A History of Modern Computing: Second Edition*. The MIT Press.

[Shapiro 1999] Shapiro, Carl and Varian, Hal (1999). *Information Rules*.
Boston: Harvard Business School Press.