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WAPI: A Chinese Attempt to Establish Wireless Standards and the International Coalition that Resisted

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Abstract:

This case narrates a standard dispute between competing industrial coalitions in China and the U.S., both having an active involvement of the national governments. Specifically, the Chinese government organized the R&D of wireless local area network (WLAN) standards and tried to use them to replace the incumbent technologies controlled by international giants in the information industry. However, due to the strong objection of the foreign stakeholders in the WLAN market, China's initiative eventually failed.

While there is ample knowledge available regarding successful experiences with technology standardization in the developed world, this case is unique because it deals with the unsuccessful experience of China. This case provides rare insights into the challenges that developing countries will meet in adopting indigenous technologies. It is useful for a discussion of how a country should organize its standardization activities.

Keywords: China, developing countries, indigenous technologies, standard, standardization, wireless local area network (WLAN)

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I. INTRODUCTION [1]

This case is about China's attempt to establish a set of wireless standards and further implement them in its market, and the international resistance to it. It aims to help us understand how, in the background of globalization, technology standardization may become a political issue and a matter of international trade concern, and how both technological organizations and governments can influence the standardization process.

The case is documented as consisting of two parts: the case body and three appendices. Following a "story telling" and "process-oriented narrative" line, this case is structured as a chronological description of key events. A general picture of the technology standardization process, which includes a standard development phase and a standard implementation phase [David and Greenstein 1990], will be presented. In Appendix 1 we will introduce the aftermath of this case. In Appendix 2, to facilitate readers' understanding of this case, some important theoretical concepts concerning standards and standardization will be discussed. We will also introduce the background of the case. Specifically, we will delineate China's national R&D policy and the relevant WTO rules on fair competition and trade issues. Appendix 3 describes case research methodology and lists the bibliography.

II. STANDARD DEVELOPMENT

A standard is a set of technical specifications of a technology or product. Standardization is the process of standard development and implementation [David and Greenstein 1990]. As early as June 2001, the Ministry of Information Industry (MII) of China published a plan for drafting national and industrial standards in wireless broadband fields. According to MII, this standardization initiative was designed to meet the requirements of the market. Specifically, in China, on the one hand, more and more individuals were ready to use wireless access to the Internet, and the wireless local network (WLAN) market was going to boom. On the other hand, the security flaws of Wi-Fi (Wireless Fidelity) restricted the interests of enterprises, government branches, etc. in WLAN services. It impacted the uses of WLAN that might evolve into areas such as wireless mobile business. To protect users from being locked into unsecured WLAN standards and also to promote the business use of WLAN technology, China believed it was necessary to develop and deploy a new security solution [Fang and Fang 2004].

Two months later in August 2001, MII formed the China Broadband Wireless Internet Protocol Standard Group (BWIPS) to undertake the R&D on WLAN standards.[2] BWIPS was designed to have 26 members to work in two projects. The BWIPS members included state-controlled research institutes and information technology producers such as Founder, Huawei and Lenovo that were in leading positions in the Asia-Pacific region. MII also appointed two liaison officials from its Division of Standardization, Department of Science and Technology to BWIPS. The two projects were respectively concerned with standardization in the media access control layer and physical layer of the WLAN protocol stack.[3]

Shortly after, in the beginning of 2002, based on the application of MII the Standardization Administration of China (SAC) included the two projects carried out by BWIPS in the issuing plan of national standards during 2002 and 2003. The two standards were given the titles of GB15629.11 and GB15629.1102. These two parts of WAPI were, correspondingly, responsible for encoding the user identity and transmitting data.

By the end of 2002, BWIPS finished the first versions of the two standards. The standards adopted a new security solution called WAPI (WLAN Authentication and Privacy Infrastructure). WAPI was a sort of elliptic-curve encryption with a block cipher. This method was more secure than Wired Equivalent Privacy (WEP) or Wi-Fi Protected Access (WPA) techniques, which were used in the current mainstream IEEE 802.11 standards.[4]

1 A teaching note is available from the author. Also, the author can electronically send this teaching case in separate parts to teachers who wish to distribute only some of the case sections to their students.
2 For the history, organization structure, task, main activities, technologies of WAPI, and working process of BWIPS, see BWIPS homepage at http://www.chinabwips.org/
3 In Chinese, GB is the abbreviation of "Guojia Biaozhun" which means "national standard".
4 For the meanings and technical properties of WEP and WPA, and the standards of IEEE 802.11 series see Appendix 2.

In December 2002, China's General Administration for Quality Supervision, Inspection and Quarantine (AQSIQ) ratified the WAPI algorithm. On May 12, 2003, SAC published the two parts of WAPI, GB15629.11 and GB15629.1102, as national standards.

On July 9, 2003, MII announced that China would refuse Wi-Fi, but would only adopt WAPI products with better security solutions. Further, on November 26, 2003, AQSIQ and SAC issued a decree, declaring that from December 1, 2003, it would be prohibited to produce, import and sell WLAN products that did not comply with the WAPI standards. Moreover, WAPI was defined as a proprietary protocol controlled by the Chinese government. It was alleged that, according to the Business Encryption Management Regulation of China, the WAPI algorithm was a national secret and hence could only be authorized to specific Chinese companies. Eleven Chinese companies, including Founder, Huawei and Lenovo as BWIPS members, were designated by the Chinese government to deploy the algorithm. Foreign equipment vendors that wanted to sell WLAN products in China were required to license WAPI through a manufacturing agreement with one of these Chinese companies.

III. THE OBLIGATORY IMPLEMENTATION OF WAPI

The plan of WAPI implementation by the Chinese government provoked strong action from foreign stakeholders of the wireless technology and market. Their immediate reaction was that they needed more time to study the technology underpinning WAPI. As a compromise, AQSIQ and SAC granted a six-month grace period until June 1, 2004, for foreign companies to comply with the obligatory WAPI standards. Yet, in the transition period, a coalition to boycott WAPI was formed, which consisted of WLAN vendors, interorganizational institutions, and the U.S. government.

The condemnation on implementing WAPI exclusively in the Chinese market came first from the U.S. Information Technology Office (USITO). As a trade group located in Beijing designed to protect the interests of the U.S. information technology industry in China, USITO voiced concerns that the foreign products would be locked out of China's WLAN market. Specifically, since the Chinese companies, many of them competing with foreign vendors, were not under any obligation to license WAPI to their foreign counterparts, they might require foreign companies to pay too high a fee for authentication [Mannion and Clendenin 2003; Walko 2004].

On November 23, 2003, the top IEEE official in charge of WLAN standardization wrote to the SAC Chairman and MII Minister. He expressed that IEEE was concerned that the Chinese security standards for wireless networks could fracture Wi-Fi, the de facto WLAN standards. To IEEE, the WAPI implementation could undermine efforts to develop a global standard for WLAN and drive up the cost of network equipment for end users. From the viewpoint of IEEE, the uniform standard was 802.11i in the process of development led by IEEE. In his letter, the IEEE official acknowledged that 802.11 security solutions needed to be improved. He offered to engage the Chinese authorities on this subject and promised that IEEE would be willing to incorporate WAPI into 802.11i to avoid splitting the WLAN product markets into two.

In January 2004, Wi-Fi Alliance participated in the debate with China on the WAPI issue. Wi-Fi Alliance claimed Wi-Fi technologies had become the de facto industry standards with an established base of customers. 802.11i was an enhancement to the incumbent Wi-Fi technology, but WAPI formed a deviation from this mainstream. In response, the Chinese side said that Wi-Fi Alliance failed to timely handle serious security flaws in Wi-Fi standards, which had hindered the WLAN market development and forced China to develop and thus obligatorily implement WAPI and reject the Wi-Fi standard family. However, Wi-Fi Alliance criticized the WAPI standards as being favourable only to Chinese companies owning the exclusive access to the encryption methods. The rules for implementing WAPI forced foreign suppliers to manufacture their chips in China, which made them worry that their confidential techniques might be leaked to their Chinese competitors. The chairman of Wi-Fi Alliance threatened that if a compromise could not be reached by June 1, 2004, its members would not ship any WLAN equipment to China thereafter [Walko 2004].

Broadcom, the largest WLAN chip producer in the world, was strongly against the Chinese requirement of obligatorily implementing WAPI. As early as January 27, 2004, its CEO told Reuters that if the only way to enter the Chinese market was using their encryption scheme, they might not commit to doing so, as this would put them at risk of disclosing their intellectual property, hence losing their technological edge.

Intel had active discussions with the Chinese government, and the relevant institutions and companies, trying to resolve the problem by the deadline [Fang and Fang 2004]. However, as confirmed by an official from MII, the Chinese side had asked for royalties that were too high for Intel to accept. On April 5, 2004, Intel announced that they had no plan to sell chips supporting China's WAPI standards.

Further, key U.S. government and industry bodies participated in this standard dispute, which made the standard setting a matter of global trade concern and a political issue [Kennedy 2006; Willingmyre 2004]. In the U.S., in February 2004, representatives from the Chamber of Commerce, Information Technology Industry Council, Semiconductor Industry Association, National Association of Manufacturers, and the U.S.-China Business Council met in Washington in an effort to squelch WAPI that was believed to undermine the essential trade efforts of the WTO (World Trade Organization) with China. They declared it unacceptable that foreign manufacturers had to co-produce WAPI products with Chinese competitors to meet a unique national regulation. To them, this rule violated the basic provision of the WTO's national treatment and involved regulatory protectionism. The meeting participants labeled the Chinese strategy of deploying WAPI standards as techno-nationalism. Specifically, they believed that the Chinese government was attempting to dominate standards and technologies by taking advantage of its market size and that multinational companies competed with each other for the Chinese market [Suttmeier and Yao 2004]. This meeting appealed to the U.S. government to take action and push China to follow its commitment to the WTO.

Some of the U.S. congressmen were motivated to voice their concerns over WAPI's implementation. They urged the U.S. government officials to be actively involved in this dispute, and requested the Chinese ambassador to the U.S. to take care of this issue. On March 31, a group of representatives even sent a letter to the U.S. President and asked him to take the WAPI case against China to the WTO.

In this situation, on the U.S. side, the Secretary of Commerce, Donald Evans, Secretary of State, Colin Powell, and the U.S. Trade Representative, Robert Zoelick, had to join the controversy surrounding WAPI implementation. On March 3, they signed the letter to China's vice premier ministers, Wu Yi and Zeng Peiyan, who were, respectively, responsible for international trade and high-tech policy. The three senior U.S. government officials alleged that the move of implementing WAPI created a dangerous precedent for using standards as a barrier to international trade. This letter resulted in bringing significant diplomatic pressure on China to negotiate a compromise.

BWIPS defended the stance of firmly holding to the published plan of WAPI implementation. BWIPS claimed it a national sovereignty for a country to set up its own standard in its own market for the concern of its own security. If foreign companies were not willing to abide by the Chinese decrees, their products would be restricted to enter into China as of June 2004.

Meanwhile, supported by MII, the Chinese manufacturers (members of BWIPS) were working hard to develop the WAPI network products. In April 2004, a few Chinese computer makers, such as Lenovo, had submitted applications to the China Qualification Centre for the certification of their WAPI products. However, only Founder, the second largest computer maker in China, reported a success. On April 5, 2004, the China Qualification Centre issued the certificate to Founder's A760 WAPI chips and access points, and its NB700 laptop that had an embedded A760 chip. However, according to two officials from MII, the access points of Founder were not compatible to the incumbent Wi-Fi technology. Moreover, they were too expensive to produce. As a result, Founder's WAPI products had no market value at all. Consequently, in fact, in China's market there were no qualified WAPI products that could substitute Wi-Fi.

The debate came to an end when the 15th plenary session of the U.S.-China Joint Commission on Commerce and Trade (JCCT) took place on April 21, 2004, in the U.S. Established in 1983, JCCT was a government-to-government forum designed to resolve trade concerns and promote bilateral commercial opportunities. This was a special session co-chaired by the Secretary of Commerce, Donald Evans, and Trade Representative Robert Zoellick, on the U.S. side and Vice Premier Minister, Wu Yi on the Chinese side. WAPI was one of the seven issues of this meeting. JCCT achieved concrete results on key concerns. With respect to its proprietary WAPI standards, China agreed it would: 1) suspend indefinitely its proposed implementation of WAPI as obligatory wireless encryption standards; 2) revise them, taking into account comments received from Chinese and foreign firms; and 3) participate in international standard bodies on wireless encryption for computer networks. In return, the U.S. promised that it would ease restrictions on the export of some high-tech U.S. products to China, and would also support China's aspiration to seek "market economy status" in the WTO.

In response to the JCCT agreement on the WAPI issue, on April 22, BWIPS published a statement. It explained that the JCCT decision did not mean that WAPI was cancelled, but that it was to be implemented in a new way. In fact, China did not give up the WAPI standards but made efforts to have WAPI ratified as the international standards, and implement WAPI in its government institutions. Meanwhile, China has learned lessons from the WAPI experience and has attempted to pursue a new strategy for R&D and standardization. These aftermaths will be discussed in Appendix 1.

APPENDIX 1: THE AFTERMATHS

Pursuing a New National Strategy of Standardization

On June 18, 2004, the annual Sino-U.S. Telecommunications Summit was held in Chicago with the attendance of China's MII Minister Wang Xiangdong and the U.S. Commerce Secretary Donald Evens. WAPI was not included in the topics of discussion. But the American National Standards Institute (ANSI) submitted a report concerning WAPI. Drafted by a group composed of U.S. information technology, telecommunications, semiconductor, and electronic companies, this report focused on China's national policy requiring adherence to the WAPI standards, which they believed would lock many U.S. manufacturers out of the Chinese market. It criticized that the Chinese government adopted a closed method to U.S. companies, disobeyed normal international practices, threatened the intellectual property of foreign companies, broke relevant WTO rules about fair competition, and damaged trade relations between China and the U.S.. The report brought up the issue of techno-nationalism, and stated that the Chinese government intended to use the globalization opportunity to pursue technology development that was beneficial to its national economy and state security [ANSI, 2004; Suttmeier and Yao, 2004].

As a response to the ANSI report, SAC issued a notice promising to improve the procedure of establishing national standards. China would promote the introduction of competition into the standardization process, and encourage cooperation between domestic and foreign companies. In standardization management, China would follow the techno-neutralism principle that allowed the market to select technologies, rather than rely on techno-nationalism [Kennedy, 2006; Updegrove, 2005]. In implementing new technology and national standards, China promised to abide by the reasonable and nondiscriminatory ("RAND") terms and conditions recommended by the International Organization for Standardization (ISO), and protect the interests of international patent owners [Willingmyre, 2004].

Implementing WAPI in Government Institutions

Facing the resistance of the U.S. with the WTO rules as the backup, China failed to implement WAPI as obligatory standards in the public market replacing the incumbent Wi-Fi. Thus, China would obligatorily implement WAPI in the government institutions instead. China claimed that this was acceptable as China did not commit to the WTO's item of government procurement. In an interview with an executive at Huawei Corportation, we were informed that the adoption of the strategy to implement WAPI in the government sector was encouraged by the fact that the home version of the Linux system was used in China. Due to the concern of security raised by the backdoors of Microsoft technology, China mandated the government sector to use the Linux system designed by Chinese software developers, which turned out to be successful [Yang, Ghauri, and Sonmez 2005].

On December 30, 2005, MII, the Ministry of Finance, and the National Development and Reform Commission jointly issued a decree that required the government sector to give priority to indigenous WLAN technologies in purchase. Further, on March 8, 2006, MII backed the establishment of the WAPI Alliance to promote the enforcement of this order. This alliance was composed by 22 domestic institutions, including Chinese telecommunications operators and manufacturers. It aimed to provide more WAPI-compatible products to the market [Basu 2006]. However, key international WLAN players were not motivated to participate in this alliance, although China signaled that it would license foreign companies to use the WAPI standards as well, dropping the prior rule of licensing only to a few domestic firms.

Fighting in the International Arena of Technology Standardization

China's effort to promote WAPI was not confined to the government sector. In July 2004, China made an application to ISO and IEC (International Electrotechnical Commission) for ratifying WAPI as an international standard. However to their surprise China found that the road to international standards turned out to be very rough.

In November 2004, the joint meeting of ISO and IEC on WLAN standards was held in Orlando, U.S.. BWIPS put the WAPI specification up for its consideration. At the same meeting, a proposal for the IEEE 802.11i standard was also submitted. However, three of the five Chinese representatives (wireless technology experts) were denied U.S. visas, and thus could not attend the meeting to discuss the technical issues underlying the two competing proposals - WAPI and 802.11i. SAC, the national standard body of China to ISO, accused the U.S. government of conspiring with IEEE to help 802.11i gain the advantage. At the request of SAC, a solution was passed which was to organize a special meeting some time later to allow technical experts to discuss the two proposals.

Subsequently, the special meeting was held in Frankfurt, Germany, in February 2005. However, the organizers removed WAPI from the agenda of this meeting on the basis of procedural rules. This move sparked a strong protest by SAC. The Chinese delegation walked out of the meeting and returned home. Shortly thereafter, SAC accused ISO of the one-sided favouring of the 802.11i proposal.

At the request of SAC, on May 17, 2005, the ISO organized another meeting to discuss the WLAN standards. A resolution was reached which agreed that WAPI should be evaluated alongside 802.11i. This breakthrough heralded further progress in August, when BWIPS and IEEE experts met in Beijing in the hope of uniting the two specifications. However, the two sides could not reach an agreement, and BWIPS later complained that IEEE's attitude was condescending [Kennedy 2006].

Soon after, in October 2005, IEEE and BWIPS, respectively, submitted 802.11i and WAPI again for ISO voting. The voting took place in March 2006. During the voting process, IEEE sent a letter to the participants to seek support, arguing that 802.11i was a stable, complete specification that satisfied the ISO criteria for approval. IEEE described that its standard was openly developed by contributions from about 30 countries. This made 802.11i an open and fully specified standard available to anyone to implement it. Further, the 802.11i was forward compatible with all planned enhancements by the IEEE 802.11 series, and backward compatible with the large, worldwide installed base of existing WLAN devices. As a result, the 802.11i standard would potentially further promote the WLAN market development. Specifically, IEEE demonstrated that Wi-Fi deployments increased from about 50,000 new devices per day before IEEE 802.11i was approved by IEEE in 2004 to presently over 275,000 new devices per day, and the installed base of IEEE 802.11i-capable devices exceeded 200 million devices globally.

The ballot ended on March 7, 2006, which saw that 30 countries cast votes on WAPI with eight votes in favour, and 31 countries cast votes on the 802.11i with 24 votes in favour. Thus, ISO overwhelmingly rejected China's domestic WLAN technology as an international standard, deciding instead to approve IEEE 802.11i as the basis for a more secure wireless protocol [Basu 2006; Clendenin 2006].

Giving the reason for rejecting WAPI, some ISO members were concerned that WAPI's development process was relatively closed and some of the underlying technologies, such as the security algorithm, had not been disclosed. This meant ISO members were not able to guarantee that WAPI would not allow backdoor access to encrypted materials. There was also a concern about WAPI's incompatibility with 802.11i and its predecessors [Basu 2006; Clendenin 2006].

China described the ISO voting as "unjust activity, undue process, and unfair results." In both April and May of 2006, SAC appealed to ISO to overturn the vote because of the "unethical activities" of IEEE, which included organizing a conspiracy against the China-developed WAPI, insulting China, and involving intimidation and threats. BWIPS also alleged that the 802.11i was immature, as it contained a lot of technical defects and editorial errors. In the opinion of BWIPS, this new technology of IEEE did not fix the security problem as it was still based on the old algorithm of Wi-Fi. China concluded that its WAPI technology was good but the road to international standardization was full of resistance from international monopolies, which stymied the spread of Chinese technologies around the world. In support of China, some ISO members also noticed the intense lobbying by IEEE they were subjected to during the five-month balloting process. During that period, IEEE released detailed arguments against WAPI which spurred angry responses from the Chinese national standard body and worsened tensions between the groups. In this appeal made to ISO, China asked ISO to delay analyzing and announcing the voting result.

However, in June 2006, the analysis meeting was still held in Prague, Czech. IEEE declared that its offer to work with China to harmonize the WAPI technology with 802.11i was still valid. But the Chinese delegation ignored this goodwill. Once again, they walked out of the meeting with the declaration that at the meeting IEEE had manipulated the voting process and created an unfair atmosphere [Clendenin 2006].

Despite the present failure, this might not be the end of the road for WAPI to enter the market [Basu 2006]. Most of the ISO members expressed a desire to see a "harmonization" between the two standards, but 802.11i would be the foundation of any such attempt. Some countries noticed that elements of WAPI provided mechanisms that were potentially valuable additions to the current WLAN security techniques and other standards in the future. Therefore, it was believed that the voting approval for 802.11i would not be the final step in the WLAN standardization. There would always be a need for improved security mechanisms that would defend against new threats, for which WAPI could play a role [Clendenin 2006].

APPENDIX 2: CASE BACKGROUND

Standards and Standardization

A standard is a set of technical specifications to be adhered to by producers. A standard is built upon a series of technologies. A standardization process includes the standard development phase and implementation phase [David and Greenstein 1990]. An equipment vendor needs to closely follow the emergence of new standards and, if possible, actively participate in the standard development processes so that its products and technologies may fit into the specific standards. Moreover, a standard provides its adopters with the knowledge of how to implement it, and specifies for them the regulatory rules to be followed in its implementation. The adopters of a standard should involve themselves in the process of standardization of the technology to ensure its efficient implementation. The most successful technology actors would manage to dominate the standardization process and establish technological control over the key parts of the standards and hence steer the market development [Michael and Rivette 2004].

From the management perspective, a standardization initiative must accommodate a considerable heterogeneity of interests [Kennedy 2006; Suttmeier 2005]. Information technology is complex, and competition in this market tends to be fierce. To secure the success in technology design and to guarantee that the new technology supports technical compatibility with the incumbents, a standardization process normally involves the participation of different actors owning expertise in specific parts of the technology. These include manufacturers and research institutes, especially those owning incumbent standards. Compatibility is important as it supports the attainment of scale of economy and encourages the customers of incumbent technology to adopt the new standards [David and Greenstein 1990; Farrell and Saloner 1985]. Moreover, to ensure the success of new standards in the market, technology distributors, such as telecommunications network operators and service providers, should be included in the standardization process. These market players have deep understandings of the customers [Keil 2002]. Consequently, alliances, consortiums and committees become key organizational forms of standard development [Funk and Methe 2001; Keil 2002]. For example, at the international level, ISO, ITU and IEC are the most important institutions that ratify global standards. These international institutions have both governments and the industries as their members.

The government is an important organizer of technology development. It can manoeuvre different stakeholders in the technology market to participate in the standardization process. In the context that standardization becomes an international issue, a government should also protect the interests of domestic manufacturers in competition, and support them to play the dominant roles in international standardization initiatives [Funk and Methe 2001].

WLAN Technology and Market

This case is about the standardization of WLAN technology. In recent decades we have witnessed the fast development of information technology, and the broad usage of the Internet in society [Abbate 2001]. In most situations, people typically are connected to the Internet by wires. However, because of the needs of mobility and flexibility, WLAN has been widely deployed for customers located in areas such as meeting rooms, airports and cafes, etc to establish ad-hoc Internet connections and peer-to-peer networks. As an illustration, in 2000, only 9 percent of portable computers could access the Internet through WLAN. In 2007, this percentage is expected to reach 90 percent [Chang, Yu and Tsai 2006]. WLAN is expected to be a main growth factor for communication networks and services.

The most important standard family of WLAN is the IEEE 802.11 series, so called Wi-Fi. Wi-Fi was initially designed by IEEE as an inexpensive alternative to wired office networks; however, it took off in several unexpected ways (Table 1). First, people pursued technological improvements in order to enjoy fast wireless Internet connection. The first standard, 802.11, was published in 1997. IEEE soon redefined it and developed the 802.11b, which operated with speeds of up to 11 Mbps, much higher than that of 802.11 (2 Mbps). Later 802.11a was introduced into the market, offering a data rate as high as 54 Mbps. However, 802.11a used a different frequency spectrum band from 802.11b, hence did not support backward compatibility. As such, 802.11a could not carry on the installed base of customers of 802.11b and ultimately failed. In this situation, in June 2003, 802.11g appeared [Varshney 2003].

Security has been a challenge in the standardization of WLAN products. Security problems in general are caused not only by increased vulnerability due to open-air transmission, but also from difficulty in encryption with smaller devices, such as mobile handsets which have somewhat limited abilities. In addition, the unlimited mobility in ad-hoc wireless networks makes the security functions even harder. Consequently, the second element driving the evolution of IEEE 802.11 standards is the gradual improvement in the security measures. Ratified in September 1999, Wired Equivalent Privacy (WEP) is a primary security scheme used in 802.11b. WEP has originally been designed to

provide comparable confidentiality to a traditional wired network, hence the name. However, WEP uses weak 40-bit encryption, requiring all users to share a single common key which is kept in a software-accessible location. As such, WEP does not well suit mobile devices and can easily be broken [Boncella 2002; Varshney 2003].

Table 1. Multiple Versions of IEEE 802.11 Standards

Standards	Payload	Spectrum band	Security solution	Backward compatibility
802.11	2Mbps	2.4GHz	NA	NA
802.11b	11Mbps	2.4GHz	WEP	Yes
802.11a	54Mbps	5GHz	WEP	No
802.11g	54Mbps	2.4GHz	WPA	Yes
802.11i	54Mbps	2.4GHz	ASE	Yes

Due to these serious security weaknesses in the exisiting WLAN systems identified by cryptographers, in 2003, Wi-Fi Protected Access (WPA) superseded WEP to enhance the security of Wi-Fi, which, in turn, led to the use of a new standard 802.11g. However, WPA also has security flaws and hence only provides a transitional solution. Finally, the security concern for WLAN standards has promoted the development of 802.11i, which uses a 128-bit Advanced Encryption Standard (AES) algorithm to enhance the authentication features [Boncella 2002; Varshney 2003]. According to the original plan of IEEE, the 802.11i should have been published in early 2004, but this schedule was delayed.

From as early as 2001, the Chinese government started to show an interest in making efforts to improve WLAN security. China proposed WAPI to compete with IEEE standards. WAPI adopts a security mechanism called elliptic-curve encryption with a block cipher. In technology, the WAPI solution is more advanced than WEP, WPA, and AES which are based on symmetric key cryptography.

National Standard Strategies

This case is concerned with national strategies in standard competition. It is a long-standing topic of debate in the standardization community to have a unique standard or several competitive standards. It is generally recognized that both have pros and cons [David and Greenstein, 1990; Farrell and Saloner, 1985]. With the existence of multiple standards, users have more choice of technologies and networks but need to afford the cost of interconnection and interoperability. The adoption of a unique standard supports the scale of economy, but the customers might have the risk of being locked in to an inferior technology [Shapiro and Varian 1999].

Standards play an essential role in the worldwide information technology sector. Overall, a few developed countries have dominated the technology development and served as the major players in standardization. However, recently globalization has changed the economic structure of the world, with some developing countries, for example China and Korea, emerging as powerful players in technology development [Chen and Sewell 1996; Lee, Lim, and Song 2005].

In China, to ensure that its economy grows at a rapid pace, the national strategy has encouraged Chinese companies to adopt high-tech and invest in technology innovation. However, the Chinese companies have developed advanced technology mainly through foreign direct investment. They have been largely stuck at the low level of the high-tech value chain, lacking critical technology like semiconductor chips. China has become an important assembly line for products made of key high-tech parts from abroad with the addition of low-tech domestic components, as in the case of mobile handset production [Chen and Woetzel 2002; Lenton 2003]. Without controlling key technologies, most Chinese manufacturers of high-tech products have a profit margin as low as 2-3% [Cao 2004]. In this background, the Chinese government sets the strategy of “talent, technology and standard”, using the standard-centred technology approach to build indigenous technological capability [Kennedy 2006; Suttmeier 2005]. The WLAN initiative of China presented in this case is part of this policy.

China has gradually increased its endeavours to create domestic technology standards. Meanwhile, as its companies have become more innovative, China wants to promote the indigenous technology to go international and launch Chinese companies as global players [Kennedy 2006; Michael and Rivette 2004; Suttmeier 2005]. Against this background, China has made efforts to have its indigenous WAPI ratified as an international standard.

A country's national standard strategy should support the adoption of an open, sharing principle in standardization [Farrell and Saloner 1985]. This is particularly important for developing countries. Like China, usually a developing country lacks the independent R&D capability to develop standards and is weak in the commercialization of new technologies. Hence, such a country should encourage the domestic technology developers to actively seek cooperation from foreign producers and owners of incumbent standards. Moreover, the foreign pacesetters set the architecture that the new technology developers have to follow in their R&D [Morris and Ferguson 1993]. The cooperation is the basis to guarantee that the new technologies of the developing countries not only are technologically advanced but also economically have a low cost.

In promoting indigenous technologies, developing countries as the new forces in standardization are in an unfavourable position in competing with the developed countries whose incumbent standards have established significant customer bases. This is due to the effect of network externality for standardized technologies, which means that the utility of a good for an individual adopter is dependent on its user size [Arthur 1996; Katz and Shapiro 1986]. The developing countries should cooperate with foreign owners of incumbent standards so as to be able to understand the incumbent technologies and thus ensure the compatibility between two generations of standards. For a new standard, compatibility with the incumbents is the basis of attracting users, operators and manufacturers to form a value chain for its implementation [David and Greenstein 1990; Farrell and Saloner 1985].

To promote international cooperation in standardization, ISO has proposed the RAND principle. The RAND principle favours techno-neutralism. This means a country should avoid the subjective interference in technology standardization, but let the market decide which standard to use [Willingmyre 2004]. However, China is often criticized for adopting techno-nationalism in standardization management. Techno-nationalism calls for using the globalization opportunity to pursue technology development that is beneficial to the national economy and state security. As domestic industries are too weak to dominate standards and technologies, the state has to be involved. With limited power, the state would work together with other sources, like the market size advantage and multinational companies competing for the domestic market, in order to promote technology development [Suttmeier and Yao 2004]. In fact, techno-nationalism only works conditionally. In the case of WAPI, the government could use the market as a leverage to try to allure foreign manufacturers to adopt its indigenous technologies, but it could only play a limited role in standard competition as WTO and ISO set the rules of the game.

In general, a country's standardization management strategy is a part of its national systems of technology R&D. In China, R&D administration adopts a planned system. The government organizes the development for a wide range of key national standards, including the standardization of WLAN technologies. It is the government that decides the standardization projects, forms the R&D force to undertake the research work, and promotes their diffusion in the market. Some important interest groups for the technologies, including customers, competitive technology developers etc are often excluded from participating in the standardization process. In particular, with national security used as an excuse, foreign cooperation is often rejected [Rao, Lu, and Zhou 2004]. However, the success of a standard depends on whether the standardization organizer could form a cooperative network that is able to attract the participation of important interest groups, including the foreign owners of incumbent technology [Keil 2002]. China needs to reform its national system of R&D management.

APPENDIX 3: RESEARCH METHODOLOGY AND BIBLIOGRAPHY

The case has been developed from three kinds of data sources, including BWIPS Web site, interviews, and written materials. We follow the WAPI events by regularly browsing the BWIPS homepage. This Web site has both Chinese and English versions with domains including “memberships,” “technology,” and “activity.” The “membership” domain introduces the organization structure, history and task of BWIPS. The “technology” domain describes the technical components and specifications of WAPI. The “activity” domain is specifically useful as BWIPS has documented there the critical events of WAPI standardization, important governmental decrees and official reports, and typical comments from both the public and official media.

To understand the WAPI standardization process, we interviewed seven experts including people from the MII of China; Beijing University of Posts and Telecommunications; Huawei Corporation; China Telecom; and China Unicom. These interviewees are familiar with the Chinese R&D policy and the standardization administration system. We also refer to large amounts of written materials. First, we refer to international magazines and official newspapers. Specifically, the *Electronic Engineering Times* and *BusinessWeek* help us understand the foreign perspectives; *People’s Daily* (published in English by the State Council of China) provids important reference to the background of policy making in China. Second, we gather information from briefings published by authoritative institutes of China and the U.S., for example, BWIPS, Office of the United States Trade Representative, and USITO. Third, we abstract data from the archival documents of government decrees and statements, and reports of other kinds of institutions like IEEE and ISO. Last, we rely on relevant academic publications in the areas of standardization and China’s information technology industry. The bibliography of this case is listed as follows.

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