**Wi-Fi Networks and the Reorganization of Wireline-Wireless Relationship**

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**Abstract**

While it is quite natural for us to be drawn to the new potentialities WI-Fi represents, we should give pause and place it within its proper context and take a long-term view of the phenomenon. One of the repeated shortcomings of the research on new technologies has been that the researchers have time and again studied them in isolation. A new technology does not strike roots and grow on a virgin ground. Instead, it encounters a terrain marked by old technologies. The new technology's growth then is shaped not only by its own potentialities but also the opportunities and restraints created by the systems based on old technologies. In order to expand the perspective beyond Wi-Fi to those that preceded it, this paper draws on the framework provided by Infrastructure Development Model (IDM), which delineates eight stages through which infrastructure networks (railroads, telegraph, telephone, and others) typically go through in their development, to study its emergence.

**Keywords**

Wi-Fi, wireless, cellular, mobile, hot spots

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The "new" of a new technology invariably captures our imagination. The emerging Wi-Fi, short for wireless fidelity, technology has much to offer that is new and spectacular. It allows ordinary people to extend the Internet into the wireless arena through relatively inexpensive and easy to install wireless links. Interestingly, by creating these links they make the Internet more accessible not only for themselves but also strangers who wander into the hot spots their transmitters generate. The growing awareness of Wi-Fi coupled with falling equipment prices have energized technology enthusiasts to create their own hot spots and in the process contribute to the development of an entirely new kind of a bottom-up network. In many ways, the activities of these technology enthusiasts are fueled by the same libertarian impulse that drove the creators of the original Internet. At a time when many fear the rationalization of the Internet by commercial forces, we are seeing an insurrection by libertarian bands of sorts who take pleasure in subverting corporate frameworks. Only time will tell whether or not this insurrection will rearrange the communications landscape or get subdued by corporate interests and fizzle out after a brief but pregnant moment in history.

While it is quite natural for us to be drawn to the new potentialities Wi-Fi represents, we should give pause and place it within its proper context and take a long-term view of the phenomenon. One of the repeated shortcomings of the research on new technologies has been that the researchers have time and again studied them in isolation.

A new technology does not strike roots and grow on a virgin ground. Instead, it encounters a terrain marked by old technologies. The new technology's growth then is shaped not only by its own potentialities but also the opportunities and restraints created by the systems based on old technologies. In order to expand the perspective beyond the new technology to those that preceded it, this paper draws on the framework provided by Infrastructure Development Model (IDM) (Sawhney, 1992). IDM, which delineates eight stages through which infrastructure networks (railroads, telegraph, telephone, and others) typically go through in their development, captures the motif that recurs whenever America creates its infrastructure networks. While research on other countries is limited, studies on infrastructure networks in France and Canada indicate that patterned growth of infrastructure networks also occurs in other socio-cultural contexts. However, each country has its own infrastructure development pattern (Sawhney, 1993, 1999). Since this paper uses the analytical framework provided by IDM which is derived from the American experience, the analysis of Wi-Fi networks in this paper will be limited to the U.S.

The first section provides an overview of IDM and thereby sets the framework for the rest of the paper. The next section examines the evolution of wireless technologies before the advent of Wi-Fi. It discusses why for a while it seemed likely that wireless technologies would break out of the mold and not follow the development pattern indicated by IDM. The third section examines the development of Wi-Fi and finds that it seems poised to follow the IDM pattern. The concluding section ponders on the future development trajectory of Wi-Fi technology.

**Infrastructure Development Model**

The infrastructure networks in the U.S. tend to develop in a decentralized, uncoordinated, and bottom-up manner. Their development is not guided by a blueprint, a grand plan, or a vision of any sort. They sort of emerge. This peculiarly American process is a reification of the country's political ethos. As Anderson (1985) points out, "the American political and problem-solving style is incremental, not synoptic—this country is wary of large-scale blueprints" (p. 280). While the polycentricity of the American socio-political environment energizes the infrastructure development process by encouraging entrepreneurial activity, it creates major problems when the time comes to forge the disparate networks into a unified national system. Yet, like in other arenas of American life, operating underneath the chaos created by the push and pull of multiple centers of initiative there are unifying forces which eventually create an integrated network. This underlying pattern which gives a distinctive character to the development of infrastructure networks in the U.S. is captured by IDM (Figure 1).

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The reader will find a detailed explanation of IDM in Sawhney (1992). In this section, only the pattern underlying the development of railroads will be discussed in its entirety. In the case of other networks, only the high points of their development will be mentioned to highlight its defining characteristics.

The first major infrastructure network in the U.S. was the inland waterways. The man-made canals were used to link rivers, lakes, and oceans to create an extensive network of inland waterways. Considering the fact that the waterways, with relatively minor intervention in the form of canals, were essentially nature's creation, they do not fall within the ambit of IDM. At the same time, the waterways provided the spine around which the railroads first sprouted. Therefore they form an important part of the analysis.

Today's gigantic railroad systems started as small experimental networks far removed from each other (Stage 1). The first major commercial application of railroads was as feeders for the canal system. Typically, they were used to transport coal from the mines to a nearby canal. In essence, they filled in gaps in areas where the terrain did not allow an extension of the canal system. (Stage 2). The canal companies invested heavily in the development of railroads because they saw them as complementary networks which extended their reach and thereby fed traffic from the outlying areas into the canal systems (Stage 3). At this point in time, long-distance railroads were beyond imagination as it seemed fanciful to suppose that the railroads would ever displace rivers and canals as the chief means of transporting bulky cargo over long-distances. Eventually, the development of long-distance capabilities tied the once isolated railroad islands into an integrated system (Stage 4). With the emergence of an integrated system, the railroads became competitors to the canals, and the earlier complementary relationship was decoupled (Stage 5). The railroads became the dominant system, and the canals saw a rapid decline (Stage 6). Now, only those elements of the erstwhile canal system survive which can play a useful role in the new order (Stage 7). After the collapse of the canals, the railroads almost totally dominated other modes of transportation for many decades. But the cycle did not stop here as a new technology appeared on the horizon—automobiles (Stage 8).

The railroads developed an expansive national network but they could not get around the feeder problem similar to that of the canals. Quite simply, the railroad network could not be extended to each farm or factory. The farmers and factory owners had to haul their goods to the nearest railroad track. Within this context, the automobile generated much enthusiasm because of its potential to extend the railroad's catchment area by moving goods and passengers from the surrounding area to the railroad tracks. The railroads made a concerted effort to encourage the development of roads to expand the use of automobiles. So much so, they started "good roads" trains that took road building equipment into the countryside and helped communities build roads. In an eerie parallel to their own history, the railroads encouraged the development of roads without ever imagining that automobile would one day develop long-distance capability and thereby become competitors. As they say, the rest is history.

In the case of telecommunications networks, we see similar patterns. The telegraph network could not be extended to every office and home because of the nature of the technology, especially the need for trained operators to send and receive messages.

Consequently, the problem of getting the message from the central office to the designated person was the weakest link in the telegraph system. The telephone was seen as the feeder technology which would fill in this gap. At that time, the conventional wisdom was that telephone would never develop long-distance capabilities because of the technical challenges involved. Furthermore, even if long-distance telephony did become possible, there would be very little demand for it as the main users of long-distance communications were businessmen who need written records of their communications. The possibility of conducting business transactions verbally over the telephone was beyond imagination. Eventually, the development of long-distance telephony displaced telegraph as the dominant communications technology.

In all the examples discussed above, we see a consistent pattern. A new technology strikes roots as a feeder to the established system and thereby is seen as extending its reach. The relationship between the new and old technology seems symbiotic and thereby stable and enduring. In effect, the new technology appears to have strengthened the entrenched paradigm. It, however, is eventually shattered with the unanticipated development of an independent system based on the new technology. IDM, which captures this pattern as an abstraction, provides a conceptual foil for analyzing the relationship between wireline and wireless networks in the next section.

**Wireline-mobile relationship**

Mobile communication first became possible in the form of walkie-talkies. They were in effect little islands of communication (Stage 1). With the advent of cellular, mobile communication became a networked phenomenon. Cellular plugged the gap between the wireline network and automobiles. In effect, it extended the reach of the wireline network into the mobile environment and thereby became a feeder technology (Stage 2). The wireline companies saw cellular as a complementary technology and invested in its development (Stage 3). At the time of the publication of IDM in 1992, it was apparent that mobile communication had followed the pattern outlined in IDM in the initial stages of its development. The big question then was whether or not the development process would move onto next stage (Stage 4) where the new system starts de-coupling from the old one. At that point in time, it seemed unlikely for the following reasons.

One, the wireline companies had been major players in the cellular business right since its inception. They had every reason to keep cellular technology as a "complement to, rather than as a substitute for, their existing services" (Noll and Owen, 1987, p. 10-11). It was very unlikely that they would do anything that disrupted the entrenched paradigm. The transfer of AT&T's cellular licenses to Baby Bells as part of the MFJ settlement had further strengthened their position. On the other hand, if new entrants in the telecommunications arena had acquired control over cellular, the entire dynamic would have been very different. They would have sought to dislodge the entrenched system and not merely fit within it. While the existing industry organization seemed immutable at that point in time, it was not sufficient reason to believe that the unexpected will not happen. After all, in their heydays, the railroads and the Western Union's telegraph monopoly also seemed to be invincible. This circumstantial factor was perhaps of a short-term nature that would dissipate over time.

Two, the inter-modal compatibility of modern communications technologies was likely to change the dynamics of network development. In the case of transportation systems, inter-modal compatibility was poor, as goods had to be physically transferred from one system to another when they were complementary to one another. For example, coal that was shipped by the railroads from the mines to the canals had to be unloaded from railroad wagons and carried to the barges. Within this context, the benefits of disrupting the complementary relationship between the old and new technology and creating a new integrated system around the new one were great. On this score, the situation is very different in the case of modern communication technologies. The information can relatively easily be transferred from one mode to another, mobile to wireline to mobile. This was not always the case with earlier communication technologies. For example, telegraph messages could not be seamlessly carried over to telephone and vice versa. Today, digitization and the accompanying development of translation technologies have greatly mitigated inter-modal transfer problems and thereby removed one important impetus for creation of an integrated system.

Three, the new technology in this particular case, mobile, required a scarce resource—spectrum. On the other hand, the old technology, wireline network, conserved this very same resource. In such a case, a complementary relationship is advantageous because it optimizes the use of spectrum. Cordless phone, a relatively simple commonplace technology, illustrates the point. The low powered transmitter on the base station allows for mobile communication within a 75-yard range. On the other hand, the base station itself is connected to the wireline network. In this configuration, the wireline network provides connectivity with the rest of the world without consuming the spectrum, while the low powered transmitter provides mobility where it is needed and yet limits the use of the spectrum to a small area. If the system were to go entirely wireless, it would use far more spectrum than a hybrid arrangement. The same archetypal pattern can be found in the architectures of PCS networks, wireless LANs, and other wireless networks. Thus it would seem that wireless technologies, because of the mobility they offer and lower implementation costs, would become the primary interface between the subscribers and the telephone network. The public telephone network itself would remain by and large a wireline network that provides high-bandwidth transports and universal connectivity. While the wireline network will be pushed to the background as mobile interfaces grow, it will remain the vital backbone of the entire network.

Of these three factors, while the first one looked like a formidable barrier for the movement of mobile beyond a complementary relationship with the wireline network, it could be discounted as a circumstantial factor. The other two factors seemed far more insurmountable because they suggested major changes in the relationship between the old and the new technology at a conceptual level. Considering all these factors, it seemed unlikely that mobile would develop along the path suggested by the IDM. But then, IDM also suggests that one should expect a surprise somewhere down the line. As we shall see in the following section, this surprise shows up in the form of Wi-Fi technology.

**Wi-Fi networks**

The Internet, for most of its history, piggybacked on wireline networks. As it grew into a popular medium used by a large number of people on an everyday basis, telecommunications companies started sensing potential in wireless technologies that would allow mobile access to the Internet. They invested large amounts of monies in 2.5G and 3G networks that sought to provide mobile Internet access over the cell phones. These initiatives by and large were not successful as these systems did not provide functionalities that the consumers were willing to pay for. One notable exception is DoCoMo's I-Mode in Japan. It is built on a very innovative business model wherein the I-Mode web sites charge micro-payments of few cents per transaction or monthly subscriptions of less than $5 that are paid through the cellular phone bills. DoCoMo has control over both the service providers, who have to win DoCoMo's approval to provide service, and subscribers, who can be denied service if they do not pay up, and thus can create a very safe and secure environment for I-Mode transactions. But then, the planned nature of I-Mode raises the question whether it is the same as Internet or a highly sanitized version one that is masquerading as the real thing.

While the corporate world has either stumbled with its mobile Internet projects or created pseudo-Internets like I-Mode, a grassroots phenomenon in the form of Wi-Fi network seems poised to overturn the corporate apple cart. Interestingly, the cordless phone once again provides a good model for understanding this new technology. Initially, the Wi-Fi technology was directed at creating mobility within a building. Just as a cordless user can walk around the house or office while talking over the telephone, the early Wi-Fi networks sought to create similar mobility for Internet access via laptop computers. Instead of directly connecting a high-speed line (telephone or cable) to a computer, it was connected to a low powered transmitter that communicated with laptops within its range. The Wi-Fi users were thus able to move around their houses and offices with their laptops while maintaining Internet access. The technology took a new turn when users started leaving these Wi-Fi transmitters unsecured. This allowed their neighbors and others within the unsecured transmitter's range to use the Internet connection for free. The people who left their transmitters unsecured did not care because they were paying a flat monthly fee for Internet access. Unauthorized use by others did not cost them anything [1]. In fact many take pleasure at the subversive nature of their actions. So much so, several hundred Wi-Fi boosters from all over the U.S. have listed the location of their networks on freenetworks.org web site (Harmon, 2002). As Negroponte (2002) explains:

> Depending on the intervening materials, a vanilla Wi-Fi can radiate more than 1,000 feet. Since I live in a high-density area, my system reaches perhaps 100 neighbors. I do not know how many use it (totally free)—frankly, I do not care. I pay a fixed fee and am happy to share.
>
> Because further down the street, beyond the reach of my system, another neighbor has put in Wi-Fi. And another, and another. Think of a pond with one water lily, then two, then four, then many overlapping, with their stems reaching into the Internet (online) [2].

The water lily imagery nicely captures the complementary relationship between Wi-Fi and wireline Internet. The flower symbolizes the hot spot, the circular area generated by a Wi-Fi transmitter within which Internet can be accessed, and the stem represents the telephone or cable line that connects the transmitter to the Internet. The overlapping water lilies allude to a high concentration of hot spots in parts of Silicon Valley, Boston, and other urban areas that overlap to create fairly large Wi-Fi patches.

So far, Wi-Fi's development pattern has stayed within the mold of earlier mobile technologies, i.e. it has not gone past Stage 3 of IDM. However, it seems poised to go onto Stage 4 in a totally unexpected way.

> In the future, each Wi-Fi system will also act like a small router, relaying to its nearest neighbors. Messages can hop peer-to-peer, leaping from lily to lily like frogs—the stems are not required (Negroponte, 2002, online).

What Negroponte is suggesting is not mere fantasy but actually possible. As explained later, "lily to lily" communication has already started occurring on a small scale. If the trend continues, we could start seeing a bypass of the old technology which is characteristic of the Stage 4 of IDM. Interestingly, the industry's reaction to the emergence of Wi-Fi networks is already that one usually sees in the Stage 5 of IDM. Quite clearly, the industry perceives a threat in Wi-Fi technology.

> Until now Wifi (sic) has been viewed by many technology analysts as an upstart from-the-bottom technology that has the potential of upsetting other capital-intensive technology deployments, like the expensive next-generation data-oriented cellular networks known as 2.5G and 3G that are being established by companies like AT&T Wireless, Cingular, Nextel, T-Mobile, Sprint and Verizon (Markoff, 2002b, p. C1 and C4).

The industry's response to this threat is even more telling. Like the canals, railroads, and telegraph, it seeks to accommodate the new technology within the existing order by strengthening the complementary relationship between the old and the new technology.

> It (VoiceStream Wireless) announced in mid-March that it will integrate Wi-Fi technology . . . with its existing network to provide "seamless service"—an Internet connection that switches automatically from Wi-Fi to 3G and back—starting early next year. Sprint PCS is working on something similar, although it hasn't unveiled an offering. "There is no question that Wi-Fi will be complementary to 3G wireless," says Sprint spokesman Dan Wilinsky. Already, Nokia and Ericcson are working on handsets that allow seamless roaming (Stone, 2002, online).

There is widespread consensus among 3G companies that Wi-Fi is a complementary technology. The headlines in the trade press now proclaim "a marriage of convenience," "Wi-Fi and 3G Can Coexist," or more simply "Wi-Fi Complementary to Telecoms" (3Gnewsroom, 2003; Olavsrud, 2003; O'Shea, 2003). According to Deutsche Bank analysts Viktor Shvets, Nigel Coe, Edward Bryant, and Andrew Kieley ". . . the probability of large-scale disruption to existing platforms remains low . . . Indeed, our analysis suggest that Wi-Fi is entirely complementary to existing fixed broadband products" (quoted in Olavsrud, 2003, online). They go on to project that the telecom industry "will simply strap the Wi-Fi platform onto existing bundles, making Wi-Fi just another piece in their product armory" (quoted in Olavsrud, 2003, online). Echoing a similar sentiment, John Stanton, chairman of T-Mobile USA, calls Wi-Fi "a piece of the puzzle" (quoted in Elgin, 2002, online).

When viewed from within the existing framework, a complementary relationship between cellular and Wi-Fi makes a great deal of sense because the strengths and weaknesses of the two technologies complement each other. Wi-Fi offers much greater bandwidth and therefore higher transmission speeds mainly because it employs low powered transmitters for communication over short distances. It, however, is limited to high population density areas. Cellular, on the other hand, has an extensive network already in place. Its downside is significantly lower transmission rates. Therefore a seamless service that automatically switches back and forth between the two networks would be a win-win solution for everybody. While in the downtown area a subscriber could use higher bandwidth Wi-Fi networks and then switchover to cellular service when driving into the outlying areas.

Having bought into the notion of a complementary 3G-Wi-Fi relationship based on the above discussed logic, the industry has sought to highlight other advantages of such a relationship that reinforce the comforting thought of a peaceful coexistence. Many commentators have suggested that Wi-Fi will encourage use of wireless data technology and thereby prepare the consumers for the 3G networks (3Gnewsroom, 2003; Elgin, 2002; Hatton, 2003; Hirsch, 2002; O'Shea, 2003; Stone, 2002). In effect, Wi-Fi will serve as a stepping stone for 3G networks (Hatton, 2003). "The goal: to hook users on Wi-Fi, then to push them toward 3G" (Elgin, 2002, online). Some telephone companies have started offering free W-Fi access to their DSL subscribers as a churn reduction strategy (Olavsrud, 2003). For example, Verizon provides its broadband subscribers free access to its Wi-Fi hot spots in Manhattan on the expectation that the "costs would be offset by lower churn rates – the number of customers who drop service each year – and growth in the enrollment of new broadband subscribers" (Feder, 2003, p. C2). Some telephone companies even see Wi-Fi networks as a means of accessing free spectrum (O'Shea, 2003). Telecommunications executives have variously described Wi-Fi as "an *extension* of the existing relationship that we have with users," "an *amplifier* of other technologies," and "good *appendage* to DSL" (Crockett, 2003, online; Green, 2003, online; emphasis added).

In sum, the logic of a complementary relationship is indeed compelling. IDM, however, prompts us to remember that what seems very rational within the existing framework may not remain so in a new network paradigm.

**The question of the future**

As mentioned earlier, at the time of the publication of IDM in 1992, it seemed unlikely that wireless would move beyond Stage 3 of the model because of the following three reasons: (1) industry structure, (2) inter-modal compatibility, and (3) spectrum scarcity. Subsequently, with the emergence of Wi-Fi, wireless is today on the verge of entering Stage 4. The big question now is whether it will complete Stage 4 and go to Stage 5.

When the Wi-Fi transmitters start directly routing messages to their neighbors or as Negroponte poetically says "lily to lily," wireless will enter Stage 4. But that does not mean that it will necessarily complete Stage 4. Direct communication between neighboring Wi-Fi transmitters would indeed result in the bypass of the entrenched wireline system, the defining feature of a system in the Stage 4 of the development cycle. However, at this level of development, the bypass will occur only at a local level. In a city center covered by overlapping hot spots, message from one Wi-Fi transmitter could be sent to another located many blocks away without ever touching the wireline network, neighboring transmitters relaying the message forward all the way. However, if the message has to be sent from a transmitter in one city to another, say from New York to Los Angeles, the entire dynamic changes. While theoretically one could imagine a chain of overlapping hot spots connecting New York to Los Angeles, the obvious advantages of using the existing wireline network would make the construction of a transcontinental Wi-Fi link impractical to say the least. In other words, even with the emergence of Wi-Fi, inter-modal compatibility remains a factor that could potentially deflect the evolution of the wireline-wireless relationship away from the IDM pattern. Similarly, spectrum scarcity continues to be a constraining factor that reinforces the continuation of the existing complementary relationship. Yet, even if the present framework endures, there are likely to be significant changes in the wireline-wireless equation as wireless grows deeper into the network and the wireline recedes into the background as a long haul transport vehicle. We are already seeing the deployment of Wi-Fi as a backhaul link, as opposed to the end-user link that has been the focus of the discussion so far, which connects unwired collection point towers to the wireline network. The advantage of Wi-Fi over microwave as a backhaul link is that it is not as severely constrained with regard to line of sight issues (Wilson, 2003).

With regard to industry structure, there has been a radical new development. Ordinary citizens operating in a bottom-up mode deployed the earliest Wi-Fi networks and are now a major force behind the development of the technology [3]. For example, Silicon Valley has hobbyist groups like Bay Area Wireless Users Group and Bay Area Wireless Regional Network that are working to cover the Bay Area with Wi-Fi networks (Markoff, 2002a, 2003a) [4]. In the past, when a new technology supplanted the old one, it was a result of corporate battles fought in the market place. The corporate interests invested in the old technology sought to protect their franchise while new firms sought to use a new technology to dislodge them. We see the beginnings of such a battle in the current scenario with different types of corporations entering the Wi-Fi arena [5]. But we also see a very different phenomenon as corporate interests as a whole are arrayed against a loose collection of ingenious technology enthusiasts driven by a libertarian impulse. It is not clear how this dynamic will shape the competition between Wi-Fi networks and the earlier more established technologies.

Arthur C. Clarke classifies forecasting failures into two categories: "failures of nerve" and "failures of imagination." In the case of the former, the forecaster fails to see the obvious even when all the relevant facts are in front of him or her. The latter occur when the forecaster is unable to make the leaps of imagination necessary to grasp a new phenomenon (Clarke, 1962). The above analysis of the potential development of Wi-Fi technology in Stage 4 is quite reasonable and that is probably its greatest weakness. As we have seen time and again, future is rarely a logical extension of the present. IDM goads us to think differently.

**IDM based projections**

It is foolhardy to make projections about the future. Yet, in the realm of telecommunications future is a pesky problem that can not be wished away. We are constantly faced with decisions about the future even though we do not know what it will entail. What technology should a company deploy to meet future demand? What regulatory frameworks should the regulators create that can cope with the pace of technological change? We have to act today and in order to do so we have to have some notion of the future, however tentative and ill formed. We would like to devise computer models that printout a detailed roadmap. But the processes driving technological change are too complex to model. We can fall back on raw haunch and intuition but that can lead to impressionistic and historically uninformed decisions. Or, as this paper suggests, we can use heuristic models such as IDM to expand the range within which our imagination roams.

One of the primary reasons for the shortfall in our imagination is that our thinking is unable to go past the prevailing logic of the day. We seek answers within the confines of the entrenched structures. In the case of Wi-Fi, our mental energies are directed towards somehow fitting Wi-Fi within the prevailing scheme of things instead of considering new network architectures. IDM provides a springboard for breaking out of this mindset.

With that objective in mind, one can venture to make two projections. The first one challenges the fundamental assumption underlying the prevailing thinking about Wi-Fi. The second highlights a blind spot.

1. *Even if Wi-Fi and 3G end up as complementary technologies, long-distance-short haul alignment will not be the basis of such a relationship.*

The seeming snugness of fit between a long distance and a short haul technology is often deceptive if the past is anything we can go by. The canal companies invested in the early railroads enamoured by their potential to draw in traffic into the canal system from difficult to reach areas. The railroads were seen as short haul technologies that increased the canal system's catchment area by penetrating terrain into which the canals could not be extended. In fact, it was a canal company, Delaware & Hudson, which brought the first locomotive to the America. The company imported "Stourbridge Lion," an English made engine, to transport coal over a 16 mile stretch from Honesdale to Carbondale (Thompson, 1925). However, the engine weighed seven tons instead of the specified three tons (Ringwalt, 1888). "The locomotive when tried out proved so heavy that they were afraid the track wouldn't sustain it, so it was discarded—but the damage had been done. The canal had taken to its bosom the serpent which later was to sting it to death" (Harlow, 1926, p. 78). The eventual development of long-distance railroads disrupted the cozy complementary relationship between the canals and railroads leading to the near total decline of the former. Of course, all this was difficult to imagine when the railroads nicely fit in as little pieces of a larger canal-centric jigsaw puzzle. As discussed earlier, a similar pattern was repeated in the case of railroads and automobiles and telegraph and telephones.

There are notable differences between 3G-Wi-Fi relationship and the ones mentioned above. Wi-Fi was at first seen as a threat by 3G interests and only later on came to be viewed as a complementary technology. This order is reverse of that of canal-railroad, railroad-automobile, and telegraph-telephone relationships where the new technology was at first seen as complementary and only later on became a threat. Furthermore, the earlier relationships were between a backbone technology and a feeder. In the case of 3G and Wi-Fi, both of them are feeder technologies that draw traffic into a primarily wireline network. Yet, in spite of all such differences, IDM cautions us against lulling ourselves into the belief that today's long distance-short haul complementary relationship will continue into the future.

Already there are signs that Wi-Fi will not forever remain a short haul technology. While the maximum range of Wi-Fi is generally considered to be 300 feet, community-networking activists have attained transmission of about 4 miles with homemade antennae using empty boxes of Pringle potato chips. According to the Guinness Book of World Records, the longest Wi-Fi link is 192 miles, created by the Swedish Space Corporation and Alvarion, an Israeli company (Talacko, 2003). The FCC has limited the power of devices such as remote controls, garage door openers, and cordless phones that make use of the unlicensed spectrum in the Industrial, Scientific, and Medical Band to 1 watt so as to minimize interference and maximize the reuse of the spectrum. It is this 1watt constraint that limits the reach of a Wi-Fi transmitter to a 300 feet radius. But then, a Wi-Fi transmitter need not be omni-directional. Directional transmitters that transmit in straight lines, as opposed to circles, can attain greater distances as the available power is channeled along a single path and not dissipated in all directions (Johnston and Snider, 2003). The Wi-Fi enthusiasts are exploiting this potential to tease out greater and greater transmitting range from a 1watt transmitter.

There are now new terms such as Wi-Max or Wider-Fi for the newer Wi-Fi technologies with greater ranges. Correspondingly, the visions of what can be achieved with Wi-Fi are expanding. According to Johnston and Snider (2003), "Starbuck's 'hot spot' is a grossly constrained vision of the future of wireless networking" (p. 8). The talk is now of hot spots, hot zones, hot pathways, and hot regions (Johnston and Snider 2003, Levy and Stone, 2002). For example, two community groups, SFLAN and Bay Area Research Wireless Network, have set up 12 public nodes in San Francisco that are linked to each other in a simple mesh configuration (Markoff, 2003b). Similarly, on a commercial basis, WiFi Metro has positioned antennas to cover a six-block area in Palo Alto and San Jose. Furthermore, companies like SkyPilot are looking to cover wider areas by "hopscotching bandwidth" from computer to computer (Levy and Stone, 2002). People have even started thinking of a future cooperative wherein users create ad hoc networks themselves instead of relying on service providers (Curry, 2001; Schrage, 2003).

> The concept is to create a Wi-Fi cooperative that turns individual laptops into potential nodes, routers, and hubs of a global network analogous to the wireless-mesh networks being pursued by Intel, among others.
>
> So treat every laptop as a voluntary Wi-Fi hot spot. People could go online to retrieve software that effectively turns their machines into Wi-Fi access points. Instead of paying for broadband Internet subscriptions, individuals—and organizations—would agree to make their machines accessible to other machines, creating relays that eventually reach the Net (Schrage, 2003, p. 20).

If the cooperative idea develops legs, it will start snowballing as every new member added to the network will increase its overall reach as opposed to increasing costs in the case of cellular data networks (Markoff, 2002a, p. C4).

In sum, the past experience with railroads and other technologies suggests that the complementarity between 3G and Wi-Fi on the basis of long-distance-short haul alignment is unlikely to be a lasting arrangement. This projection, however, does not preclude the potential co-existence of 3G and Wi-Fi. It is quite likely that the future wireless environment will be a heterogeneous one with multiple technologies co-existing (Lehr and McKnight, 2003; 3Gnewsroom, 2003). In this milieu, both 3G and Wi-Fi may co-exist. But the basis of their co-existence is unlikely to be long-distance-short haul complementarity. It may be mobility, less likely with development of Wi-Fi handoff technologies, or some other basis that is difficult to imagine right now.

2. *While our current thinking is dominated by the relationship between Wi-Fi and 3G, IDM predicts that Wi-Fi's main impact will be on the network core.*

Both Wi-Fi and 3G are what Lehr and McKnight (2003) call "edge-network" technologies. In other words, "they offer alternatives to the last-kilometer wireline network. Beyond the last kilometer, both rely on similar network connections and transmission support infrastructure" (Lehr and McKnight, 2003, p. 357). Our focus to date has almost entirely been on the two edge-network technologies. We have given very little thought to the impact they may have on the core wireline network itself.

When some thought has been given to the relationship between Wi-Fi and wireline network, the focus has been on the backhaul links connecting hotspots to the IP backbone. According to Deutsche Bank analysts Viktor Shvets et al., “the natural advantage of owning the backhaul connection, confers upon ILECs (Incumbent Local Exchange Carriers) a status as the best-placed operators to take advantage of Wi-Fi penetration growth” (quoted in Olavsrud 2003). On the other hand, Wi-Fi networks, especially unsecured ones that open up a DSL line or cable modem connection to neighbors and passers by, have also been characterized as parasitic networks (Curry, 2001). The cable and telephone companies contend that subscribers who leave their transmitters unsecured are violating their service agreements and possibly breaking the law. They equate allowing neighbors and strangers to tap into one’s Internet connection to cable theft. Wi-Fi enthusiasts argue that satellite broadcasts provide a more appropriate analogy. It is not a crime to pick up unscrambled satellite signals. However, it is against the law to decode the encryption of scrambled signals. In other words, securing connections is the responsibility of the network owner and not the users. These arguments have not yet been tested in the courts and it is difficult to predict how the justices will rule (Harmon, 2002). Today, the parasitic traffic is on lightly loaded network. It is likely to become a problem with the growth of Wi-Fi networks (Lehr and McKnight, 2003).

When Wi-Fi and wireline technologies are considered as potential competitors, the frame is limited to the last mile. Both Wi-Fi and 3G proponents seek to attain data speeds comparable to that of current broadband wireline service and hence could emerge as competitors to DSL and cable modem service providers. However, Gartner, a market research company, believes that wireless technologies will simply not be able to keep pace with wireline ones as we move into the one-gigabit world.

> To survive—and thrive—Gartner believes wireline carriers must use the current investment opportunity to deploy an unassailable competitive advantage. Now is the time to make an investment wireless providers cannot match because of wireless technology limitations . . . Clearly we believe enabling integrated Next-generation Broadband services is the key to survival for wireline providers (Gartner quoted in Johnston and Snider, 2003, p. 16).

Interestingly, this purported "battle for survival" is actually a skirmish at the edges—broadband wireline (last mile) edge-technology vs. broadband wireless edge-technology—rather than a contest for the heart of the network. IDM, on the other hand, predicts that a descendant of Wi-Fi, at some point in the future, will drive a stake through the heart of the network. How it will fundamentally reshape the core network will become clear only with the passage of time.

**Notes**

1. The only time people who leave their transmitters unsecured have to bear a cost of sorts is when a large number of freeloaders simultaneously download many large files and thereby degrade the quality of their Internet connection (Harmon, 2002).

2. Negroponte credits Alessandro Ovi, technology adviser to European Commission president Romano Prodi, for the lily analogy.

3. Many city governments have also started creating Wi-Fi networks as economic development and quality of life initiatives. For example, the city of Long Beach, California, has plans to provide Wi-Fi connectivity in a four-block area around the convention center and later extend it to the marina, airport, and other areas. There are similar efforts afoot in San Francisco, Seattle, Jacksonville (Florida), and other cities (Markoff, 2003a).

4. What differentiates these networks from commercial networks is that they self assemble by "expanding from one neighborhood to the next as individuals and businesses join by buying their own cheap antennas that either attach to the wired Internet or pass a signal on to another wireless node" (Markoff, 2002a, p. C4).

5. On the commercial front, many different types of players have sought to leverage Wi-Fi technology for business purposes. AT&T, IBM, and Intel have partnered to create a new company, Cometa Networks, to develop Wi-Fi networks. Its goal is to deploy by the end of 2004 over 20,000 wireless access points across the country so as to bring Wi-Fi connectivity within five-minute walking distance in urban areas and five-minute driving distance in suburban areas. Interestingly, in light of the discussion in the previous section, even Cometa executives expect cellular and Wi-Fi to be complementary technologies (Markoff, 2002b). Wayport already provides connections in 450 hotels and a number of airports. It charges corporate users $19.95 a month per employee who uses their network (Harmon, 2002). On the retail end, Starbucks shops in New York provide 30 minutes of free access to their Wi-Fi network and then charge $2.95 for every 15 minutes of additional use (Harmon, 2002).

6. The near total abandonment of the old technology in Stage 7 of IDM is also not based on economic rationality. For example, the abandonment of railroads in the U.S. with the advent of the automobiles had more to do with cultural factors than any thing else. In fact the economic rationality logic would have prompted a coordinated co-existence of old and new technologies as seen in many European countries.

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**Figure 1: Infrastructure Development Model**

**Stage 1:** Sprouting of infrastructure islands

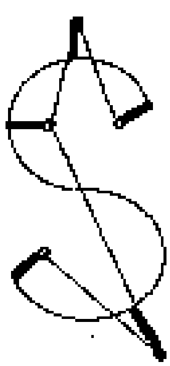
The infrastructure technologies first appear as technological islands. There is no interconnection among them and the islands are isolated from one another. These islands are hotbeds of entrepreneurial energy. They are basically demonstration projects which test out revolutionary ideas. Their actual commercial potential is still uncertain.

**Stage 2:** Development as a feeder

The new technology is found to be viable and its basic potential is seen in its role as a complement to the old system. The new technology reach into areas which were inaccessible to the old technology due to its different technological base. At this stage it is still a short-haul technology.

**Stage 3:** Encouragement by the old system

The new technology in its role as a feeder generates additional traffic for the old system. In effect, the new technology increases the old system's catchment area by extending its reach. The old system encourages and aids the development of the new technology.



**Stage 4:** Long-distance capabilities and system formation

The long-distance capabilities are developed. The isolated bits of new technology become directly interconnected and start bypassing the old system. The interconnection process creates problems of coordination and standardization. Eventually the long-distance capability results in an integrated system.

**Stage 5:** Competition with the old system

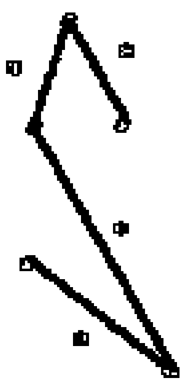
The old system finds itself threatened. At first it goes on an offensive but soon adopts a defensive posture. Charges are made about "unfair" subsidy. The need to protect the franchises of the old system is stressed Emerging competition is depicted as something wasteful. Finally an attempt is made to accommodate the new technology within the existing order.

**Stage 6:** Subordination of the old system

The old system's rearguard action is unable to withstand the onslaught of new technological developments. Eventually the old system caves in or is pushed into a subservient role.

**Stage 7:** Reversed feeder relationship

The old system disintegrates into fragments, and only those fragments which can serve a unique niche survive. They either fill in a gap where for economic or technological reasons it is not attractive to extend the new system, or they supplement it along routes where there is a specialized kind of traffic. In effect these fragments now serve as feeders for the new system.



**Stage 8:** Rerun of the above cycle

The new system dominates until another technology appears. The newer technology then grows along the same cycle. Eventually it replaces the new system. The cycle goes on. Just when it seems the ultimate technological plateau has been reached, another technology appears.

Notes:

The different "S" shapes are mnemonics for the concept "system."