Inter-organisational networks; enabling, delaying and preventative roles in the emergence of disruptive technologies.

Abstract

Disruptive change is change that radically alters an end market; typical examples of this include the replacement of vinyl records by CD and later by soft copies (mp3/iTunes etc.), the replacement of film cameras by digital etc. Disruptive change is difficult to predict and may often occur outside the market it is developed in. This paper aims to map an emerging disruptive change; that of mobile VOIP and to evaluate the role of inter-organizational networks in the emergence of this disruptive change. By delineating the steps required in a mobile VOIP call and describing the influences along this "supply" chain, the paper shows 4 stages in the "supply" chain that are typified by the traditional variables affecting technological change; competing standards; emergence of a dominant platform standard; the role of incumbent firms and emerging firms and the role of inter-organizational networks. Traditional thinking states that inter-organizational networks facilitate technological development; in this paper by delineating each stage in the supply chain, the role of inter-organizational networks is mapped; at some points, these networks have facilitated technological development but at the critical point of commercialization, what appears to be collective action by incumbent firms hinders the widespread adoption of the disruptive technology.

Keywords: Disruptive change, networks, telecoms

Introduction

“There is no reason anyone would want a computer in their home” Said Ken Olson arguing against the PC in 1977, President, Chairman and founder of Digital Equipment Corp. (DEC). Not long after this, Bill Gates insisted that “We will never make a 32 bit operating system” (Top 30 failed technology predictions, 2007). Even experts in their fields have trouble predicting which technologies will work and which will not. Large successful companies such as DEC, Kodak, and Xerox have all previously misjudged technology and market changes and suffered as a result of not being ready for the new technologies of PCs, digital cameras, and cheap copying. However these technologies were later adopted into the mainstream market, disrupting the market structure, and changing the history of these major companies. Whilst this form of disruptive change is easily seen as a retrospective issue, it is difficult or at times impossible to judge which emerging technologies will be successful.

The terms “discontinuous”, “disruptive” and “radical change” have all been used to describe this phenomenon. Abernathy and Utterback (1978) describe disruptive technologies as those that create entirely new technology-product market paradigms. Bower and Christensen (1995) state that “disruptive technologies” do not have to be radically new, but include those with superior market performance trajectories. Whilst Christensen (1997), Henderson (2006) and Henderson and Clark (1990) discuss the issues of radical, architectural and discontinuous change, these have been largely defined as innovation which involves changing the current market for a technology; these are innovations which destroy existing markets and allow markets for new products and services to evolve (Hamel and Prahalad, 1994). The converse of disruptive change has been defined as incremental change, and involves relatively minor changes to the existing product, exploits the potential of established design, and usually reinforces the dominance of incumbent firms (Henderson and Clark, 1990). This paper therefore uses the term “disruptive” as an encompassing term for large scale market-technology changes, and this incorporates what other studies call “radical” or “discontinuous”.

Recent research suggests that networks of firms, or individuals working together aid innovation (Hakansson 1990; Chesborough, 1995) but the manner in which this contributes to disruptive change is not well understood; and it may be that these “networks” are in fact very loose arrangements rather then formal agreements. Firms do not operate in isolation because interaction with other firms is essential, therefore a firm’s actions cannot be seen in isolation but as a collective action approach as first described by Olsen in 1965 (Brito, 2001). The way in which firms operate under collective action can be complex; joint or collective actions can be seen as mechanisms to push change in certain directions (Gadde and Hakansson, 1992). The “networks” caused by collective action also undergo both evolutionary and discontinuous change depending on the action of the actors; therefore the action of one actor can directly affect the actions of others. Wilkinson and Young (2002) take this idea further and suggest by examining complex adaptive systems moving from fixed stable patterns of behavior to extremely interconnected chaotic systems, there are transitions known as “edge of chaos”. They suggest that natural systems evolve towards this position of the edge of chaos because it creates evolutionary advantage, and is better able to sustain innovation. In contrast, in highly connected systems, innovation in one part of the system is likely to have disruptive influence on other parts of the system. From outside an organization, it is difficult or impossible to diagnose the difference between collective action from individual firms, and that caused by networks of firms collectively acting.

As far back as 2004, Internet Protocol (IP) telephony was predicted to replace traditional calling (Christensen, Anthony and Roth, 2004), however whilst VOIP has been adopted to a limited extent for business applications and for home use, the use of mobile VOIP is still an emerging technology. Mobile VOIP might be perceived at the market level as a convergence of two technologies; VOIP and mobile telephony. However by mapping each technology or protocol needed to make a mobile VOIP call, it can be seen that in fact a convergence perceived by a consumer or at the market level might be better explained as a result of a series of different technologies being used simultaneously to produce a new and disruptive market-technology.

Traditional thinking suggests that inter-organizational networks play an enabling role in the development of new technologies. The aim of this paper is to examine and challenge this assumption. By using an adaptation of a technological road-mapping approach, the paper delineates the steps required in a mobile VOIP call, describes these technologies and dominant standards, and examines the actions of incumbent and emerging firms, and the role which inter-organizational networks play at each step. In doing so, the paper aims to examine the importance, and influence of inter-organizational networks at each step. An alternative explanation of network collective action is proposed suggesting that market control by incumbent firms results in collective action to delay, or even prevent, the emerging disruptive technology. Smaller or more maverick firms might challenge this collective action but where this is seen this is largely a firm acting alone.

Most disruptive technologies are seen “after” they become disruptive; therefore by mapping the actions of companies at this critical stage of disruption this paper provides a unique snapshot view of the way firms interact at this critical period of time. A gap exists in the literature to follow the potential impact of disruptive technologies across different industries; to gather real time current longitudinal data, and to consider the impact of converging technologies, standards and power and influence within the supply chain. Since this is a situation that changes on a daily basis, secondary information has been drawn from a number of current sources including company websites, wikis and blogs. The history, current situation and future of mobile VOIP is reviewed, noting at each stage the role of inter-organizational cooperation or networks as either facilitating or hindering these developments.

Background

Disruptive technologies displace existing technologies, requiring changes by incumbent firms and supply chains. They cause temporary chaos in the market place until a dominant standard is adopted, and mainstream consumers adopt the technology. Identifying potential disruptive technologies and predicting their trajectory and eventual success is not only difficult but can have far reaching effects on both incumbent and emerging firms. The ability to map or measure these radical technologies has been attempted through a variety of techniques including technology cycles (Anderson and Tushman, 1990), technological trajectories (Dosi, 1992; Christensen and Rosenbloom, 1995), s-curves (Foster 1985), expert panels (Dewar and Dutton, 1986), hedonic price models (Henderson, 1993) and technological roadmapping (Rinne, 2003) and the Hypercube approach offers yet another way to examine the adoption or non adoption of disruptive innovation (Afuah and Bahram, 1995). Afuah and Bahram (1995) modeled some of these interactions in what is called the “Hypercube of Innovation”. In this model the roles of supplier, innovator, customer, core concepts (technology) and complementary innovators are considered. Using this model and historical case studies to illustrate the model, they argue that disruptive technologies which reinforce core concepts and enhance competencies within the value added chain are those most likely to be adopted. Whilst the Hypercube model extends other work in aiming to predict which disruptive technologies will be adopted, the authors note the need for multiple innovator and competitive scenarios. This notion of the value added supply chain moderating the adoption or rejection of a potential disruptive technology is also seen to happen across industries; where innovations can impact different industries. In addition where supply chains are particularly unyielding this can severely impact the adoption of a new technology (Kaufmann, Tucci and Brumer, 2003). A recent and comprehensive review of all of these techniques reveals serious inadequacies (Dahlin and Behrens, 2005) including conceptual issues such as the assumption that the new technology is better performing; that it will have an impact in the predicted industry as well as methodological issues in terms of gaining a representative sample frame and representative measures of innovation (Dahlin and Behrens, 2005).

Relatively little research has tried to form a framework of factors affecting disruptive technologies (Walsh, Kirchoff and Newbert, 2002; Dahlin and Behrens, 2005) and this can be made more difficult because until the change has been adopted, it is difficult to predict if it will be disruptive (Walsh et al, 2002), and because the disruption or discontinuity can occur in industries other than that which the technology arises in (Afuah and Bahram, 1995). Indeed, disruptive technologies in some market sectors are only sustaining to other industries (Kostoff et al, 2004). In addition, each disruptive technology may be affected to a greater or lesser extent by a wide range of factors, and whilst academic study has focused on what happens, it has with some minor exceptions, largely unanswered the question of why some disruptive technologies are adopted, and others which are equally viable are not (Dahlin and Behrens, 2005). However common threads throughout existing models suggest the following elements are influential in the emergence of a disruptive technology:

- Incumbent firms.
- The “supply” chain.
- Competing, complementary technologies, and technical standards.
- Consumers.
- Inter-organizational networks and collective actions.

The remaining sections of the paper are structured as follows: the next section briefly reviews the existing research relevant to each of the variables above. Following this, a case study approach is used to delineate and explain the different stages involved in a mobile VOIP call, the technologies involved, and where possible, the role and actions of inter-organizational networks at each stage. Finally the paper evaluates. The paper concludes with a discussion of the role of networks in enabling, delaying or even preventing the market availability of mobile VOIP.

Incumbent Firms

In mature markets, it is common for there to be a relatively small number of large incumbent firms offering a product or service. Large companies rarely introduce disruptive technologies because their revenue and customer base together with their core skills are all geared around existing technologies (Christensen 1990; Schumpeter 1942). In addition, incumbent, and especially large incumbent firms have an established value chain (be it manufacturing or knowledge based), and an established customer base; indeed, the success of existing firms is in optimizing these areas. Christensen’s research from the late 1990s and Schumpeter’s early work suggested that it is not possible for incumbent firms to succeed with disruptive technologies.

Where there are smaller incumbent firms, there is the possibility that these can act in a more versatile manner (Walsh et al, 2002), and have greater flexibility in their marketing strategies and much shorter times to market. However a counter argument exists that indicates that large firms are resource rich and can support innovative and creative R & D, whereas small firms are resource poor, and often struggle to raise venture capital. Chandy and Tellis (1998) suggest that it is not resources, but the willingness to cannibalise a market sector is a more important driver of radical innovation than firm size. In some industries, notably knowledge intensive ones, some large incumbent firms try to "hedge bets on uncertain markets and technologies" by forming alliances with start ups firms (Lambe and Spekman,1997) and waiting until a technological platform standard has been established (Hill, 1997).

The supply chain

The supply chain can accelerate or hinder new technologies by stocking and supporting the new emerging technology or by controlling the market outlets so that the new technology appears less attractive, or less easy for the consumer to access. In other cases there is a need for the new technology to be supported by other complementary technologies (Afuah and Bahram, 1995). Finally, government legislation may affect the uptake of the technology (e.g. digital TV) and force the supply chain to support the entrance of the new technology.

Consumers

Consumers also play a role in the adoption or rejection of new technologies. In some cases, consumers simply do not adopt the new technology. In others, a small number of innovative consumers lead the way (Rogers, 1995) and adopt the new technology but the technology does not become mainstream or "cross the chasm", identified by Moore (1991).This may be because new technologies are launched at too early a stage and the initial (first generation) technology is inferior; in this case, only a small number of consumers are willing to risk adopting a new platform or technology, which may be phased out if not adopted by mainstream consumers. Customers are not usually capable of giving information on disruptive technologies partly because at least initially, many customers do not understand these breakthrough technologies (Mohr, 2001; Abernathy and Utterback,1978).

Until the 1990s, the dominant view of technological change was that displacement of incumbent firms and technologies was driven by the superior performance of the technology. However this view was later challenged by Christensen (1997), who identified that inferior technology can also disrupt incumbent firms, challenging the understanding of the driving forces for disruptive technological change. The drivers for such change are not well understood (Adner, 2002), but Adner has identified two new constructs which help to explain market demand conditions. These are "preference overlap" from the consumers viewpoint and "preference asymmetry" from the firm's viewpoint which is a driving force for incumbent firms actions.

Competing, complementary technologies, and technical standards

The growing importance and emergence of technological standards for operating in many fields means this is an area of increasing importance. During the period when a new technology is being introduced, there is usually a period of considerable confusion both in terms of which technology is "best" or complementary to existing technologies, but also which will become the dominant standard. There may be experimentation with differing technologies, all of which are brought to an end by the emergence of a dominant design

(Henderson and Clark, 1990). At this time, incumbent firms compete with emergent firms, technological platforms are not yet established, and there is little agreement as to what platforms will become dominant. In recent years many firms have formed strategic alliances at this stage to ensure they are part of the emerging dominant platform technology (Hill, 1997).

Inter-organizational networks and collective actions.

In these times of increasing technological complexity, increasing R & D costs and shortened lifecycles, networks can allow technology to develop that is too expensive for one organization alone, and in general, innovation is conducted less within individual companies and more in knowledge-creating networks integrating individuals, firms, universities and other institutions (Calia et al., 2006; Mohannak, 2007). In addition, technological change does not occur in isolation but is normally contingent on complementary technologies or supporting products and services (Afuah and Bahram, 1995). Emerging firms are unlikely to have control over these complementary products or services and therefore struggle to challenge the status quo.

Different theories have been used to better understand cooperative action between competing firms. In the 4R model, Hakanssen (1990) shows that networks are often essential in bringing forward technological change. Other theories also support this idea, for example resource based theory suggests cooperation is a logical response to scare resources, and that dyads, networks or other groupings of firms might cooperate to share resources to mutual benefit. Thus the network may be required to provide sufficient resources to allow the development of new technologies whilst simultaneously and defensively acting to prevent the change towards the new replacement technology. Brito (2001) argues that networks are characterized by both change and stability; that actors within a network struggle for both stability and the actions of these actors take to increase their power or resources within the network.

Case Study - Mobile VOIP – an emerging disruptive technology

Voice over IP (VoIP) is a technology that uses Internet Protocol (IP) to IP connections for voice communications. It was first commercialised in 1995 by a company called VocalTec but due to internet connection speeds, the quality of calls was initially poor. VoIP defines a way to carry voice calls over an IP network including the digitization and packetization of the voice streams. (www.Cisco.com). These data packets transmit voice signals either over the Internet, or for mobile VOIP, the data packets can be transmitted over either cellular and internet connections. A standard VOIP call consists of 3 steps:

- the conversion of the analog voice signal into IP packets,
- transmission of the IP packets over a network (where the packets travel concurrently with other web traffic including data packets, Video over IP packets, etc.), which are directed to appropriate destinations by routers and switches,
- conversion of IP packets back to a voice signal.

Mobile VOIP is an emerging technology that allows enabled mobile phone handsets to make VOIP calls through *either* the 3G or wifi connections. There are essentially two markets for telephony; business calls and individual users, and this paper focuses solely on individual users. To the individual end user, the technology will eventually “look and feel” the same as making a normal mobile phone call and within a few years, most cellular, and some fixed landline calls will be replaced by VOIP calls. A consumer might not even be aware that a call is mobile VOIP rather than analog signal, but this emerging technology is predicted to destroy the current market for cellular calls; forcing incumbent firms to change their business models, requiring internet and 3G/ 4G providers to handle more and more digital voice data, and creating new markets. The company, "Disruptive Analysis" predicts that the number of VoIP-over-3G users will be over 250 million by the end of 2011; from virtually zero in 2007 (www.gigacom.com) and recent industry reports that the mobile VoIP market is expected to be worth $32.2 billion by 2013 and by 2019, half of all mobile calls will made over all-IP networks, according to recent industry reports (Campbell, 2005).

A brief timeline of events in this emerging industry are shown below:

1995 Vocal Tec launches first IP service

1996 VocalTec is IPO

1998 1% of all US phone traffic is via IP
(http://www.whichvoip.com/voip/articles/voip_history.htm)

1998 Cicso and Lucent enter market (approx)

2000 3% of all US calls are IP based

2002 first Blackberry launched by RIM

2003 Skype released

2007 (Jan) First iPhone launched

2007 Skype 3 handset launched (hybrid cellular/ VOIP)

2007 Open Handset Alliance forms

2011 (Jajah, Rebtel, Fring, and Zing), MuniFi, FON, and Clearwire emerge as mobile VOIP providers

Figure 1 A timeline of major breakthroughs in VOIP technology.

Telephony is a complicated set of technologies and a mobile VOIP call requires many of these enabling technologies to be in place before the call can take place. At each stage of this process, which is shown in Figure 2 below, the variables above (competition; standards; market structure; customers; supporting technologies) all combine to determine the ability to make this mobile VOIP call.

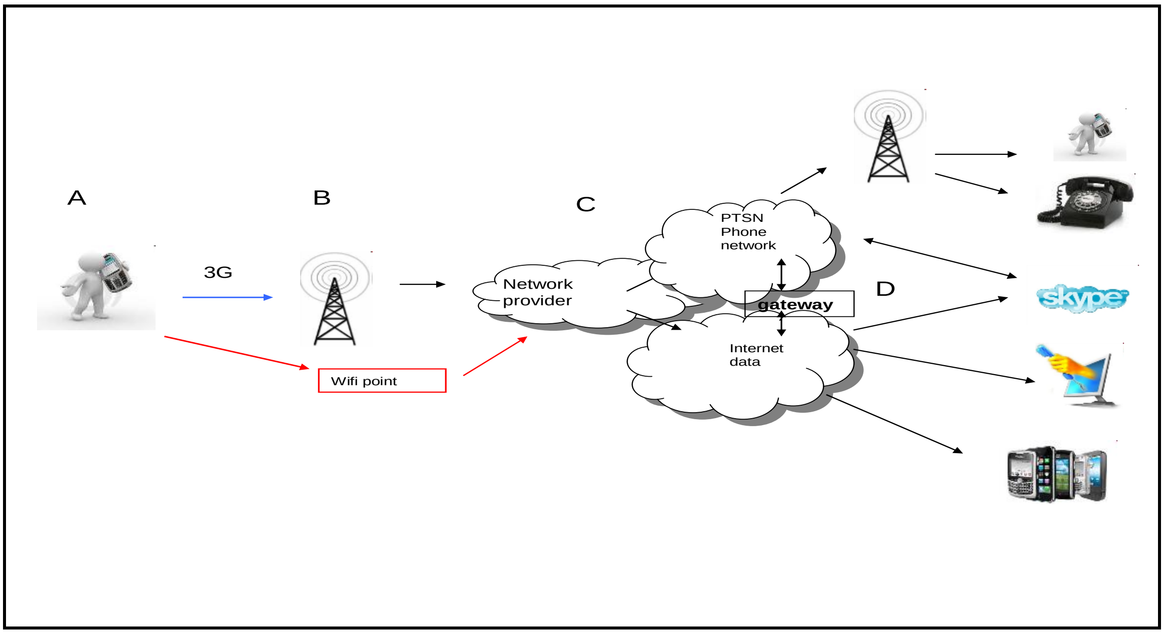

Figure 2. Mapping the stages in a mobile VOIP call

Figure 2 shows that for a mobile VOIP call to be intitiated, a smartphone is required, because the phone requires software to convert the voice call into a data stream. The data containing the call could then be routed in one of 2 ways; either by a wifi point (either within a home /office or at a hotspot), or through a 3G (or 4G) network.

The smartphone can either be enabled to be VOIP compatible by the manufacturer or to allow a VOIP application (app) to be installed onto its operating system. Once a call is initiated, an embedded software protocol, usually SIP (Session Initiation Protocol), examines the initiating and receiving devices to determine what interim protocols are compatible at each end to allow the data packet to be transferred (Rosenberg et al, 2002). Packets of digital information with a packet header identifying these as voice traffic rather than a data package (such as generated from browsing a website from a smartphone) enable the network providers to route the transmission.

This signal (now identified as voice traffic) may be prioritized, or delayed, as it passes along the next stage. Another new technology technology that can examine and tag the data stream called Deep Packet Inspection (DPI) may be involved at this stage. The data signal then enters what has become known as the “communications cloud” and is routed either via the cellular (3G) network, or via the internet to reach its final destination. The communications “cloud” at this point is complex; signals can be transferred either through the cellular networks, or through the old fixed lines, or through the internet. The voice data signal or voice signal is then transferred to its end receiver; and this can be a number of options; cellular phone, fixed landline; skype (in), traditional VOIP via PC, or smartphone and therefore the end signal could also be data or voice signals, depending on the target device.

The points A (Handsets), B (wifi availability, privacy, bandwith), C (data stream transmission) and D (termination) above in the diagram offer a simplified version of the points at which the enabling technologies exist and can be influenced by the incumbent and emerging firms. These points are therefore the ones at which the role of inter-organizational networks play an important role in the ability for this technology to be commercially available and are discussed in more detail below:

A. Handsets / Platforms and Apps

A mobile handset must be enabled to allow VOIP calls; this partially depends on the platform used on the phone, partially on the network provider who may negotiate with each handset manufacturer to determine what features are allowed on the handset, and partially on the apps allowed to be added to the handset. Therefore at this point in the path, incumbent firms, emerging firms, technology and platform standards, and inter-organizational relationships **all** play a role.

Smartphone purchases accounted for 22% of all mobile phone sales in 2010 (Anon, 2010), although the speed at which this market is changing can be seen by the fact that in April 2011, they accounted for 47% of new phone sales in that month. Whilst Nokia dominated the market for handsets in 2010, in the 12 months to April 2011 this has completely changed with Android phone sales increasing rapidly and now accounting for nearly 34% of all smartphone owned (Arthur, 2011). The rapid increase and market dominance of mobile internet usage by iPhone and android confirm the requirement for complementary technologies; without sufficient apps, consumers are unlikely to opt for a particular operating platform.

The sale of smartphones is important because it affects which platform exists at this point in the "supply chain". There are 4 dominant operating systems currently being used on smartphones, of which 3 allow the addition of Apps that allow VOIP calls. The exception to this was Symbian, but in 2011 Nokia have formed an alliance with Windows and so this position could change in the near future (Microsoft, 2011) This is summarized in Table 2. One of these operating systems was developed as a result of an inter-organizational network, the Open Handset alliance formed in 2007, which consists of many companies including Google, HTC, Intel, LG, Motorola announce the new Android phone. Within a month, several other companies joined this network including Vodafone and Sony Ericsson and a year later Android was launched as a new operating system; as seen above this has recently become one of the UK's fastest growing handset sales.

VOIP software (either an app or software embedded in operating system) is required because VoIP uses compression techniques (codecs) to make efficient use of available bandwidth. A codec (coder-decoder) is a piece of software that converts an analog voice signal to a digitally encoded version. For example, by using the G.723 compression protocol, a VoIP call can be transported using one-tenth the bandwidth of a traditional voice call, which uses a 64 kbs channel. Codecs vary in the sound quality provided, the bandwidth required and the computational requirements. Most apps or embedded software programmes support several codecs, and this is necessary because at the initiation and the termination of a phone call, the codecs need to be compatible. Although codecs vary in their quality and delay characteristics, there is, as yet, no one dominant standard, although G.723.1 and G729A are the most commonly used (ECC, 2004). The lack of standardization across the Internet has meant that thousands of bolt-on accessories have been constructed. This lack of standardization can prevent the uptake of mobile VOIP improving as rapidly as it might have been able to do had standardization been seriously considered essential at the outset. An example of this is that generally when a VoIP call is established, a codec that both parties and one supported by the provider needs to be present (Voip Pro, 2006)

Most available apps, except skype, use SIP. Session Initiation Protocol (SIP) is a peer-to-peer, multimedia signaling protocol. It was first published by an alliance formed from between AT & T, Bell labs (Alcatel Lucent), Cal Tech and Columbia University in the USA. Since its first publication in 1999, SIP has become widely used in the VOIP industry, and many people believe that SIP will become the de facto standard protocol for future voice networks (Lingfen and Ifeachor, 2004). Each of these elements are summarized in Table 1 below which also marks the enabling role of inter-organizational networks played in each of these technologies as ☼

Handset	**Operating System**	**Example Applications**	**Codec used**	**Organizations involved in Codec development**
Iphone	Apple iOS	More than 200 apps available	Multiple. May include G729	☼ France Telecom, NTT, Toshiba, Université de Sherbrooke
		Skype (free)	SILK (proprietary)	
Various: Samsung GalaxyS HTC desire	☼ Android	More than 160 currently available including Bria (paid) and Sipdroid (free)	Multiple including G729	☼ France Telecom, NTT, Toshiba, Université de Sherbrooke
		Skype (free)	SILK (proprietary)	
Nokia N95 (2007) Sony Ericsson models	Symbian	Included (but originally removed by network providers)	G711 (default), iLBC, G729	
Blackberry	RIM	None provided by around 30 available (both free and paid).		
		Skype (free)	SILK (proprietary)	

Table 1 Summary of Smartphone platforms, Apps and Codecs

B: Wifi availability / Privacy / Bandwidth

The second stage of the mobile VOIP call is the transfer of the data via the 3G network or wifi. Wifi availability is essential for mobile VOIP to work. The number of wifi hotspots in the UK is hard to determine but is very large; BT Openzone currently claims it has the largest number of wifi hotspots with over half a million sites (www.btopenzone.com). However the real number which are currently freely available to customers is as little as 7000, although BTFON network customers can access more than 2 million sites. BTFON is a very interesting example of consumers acting in a collective manner and combining together to allow other members of the FON community to use spare capacity on their wifi networks (www.bt.com). At present, there are relatively few wifi hotspots that are accessible on a free basis; the terms of use of most ADSL providers prohibit allowing sharing of the connection; in addition, providing free wifi access could potentially open up issues of users using someone else’s account to download illegal content. This collective action of incumbent firms acts to delay the availability of mobile VOIP. In addition, consumers may be reluctant to share their wifi access points as there have been several cases in the USA where the owner of an access point has been visited by police when their unsecured wifi has been used by neighbours to download illegal material (Thompson, 2011).

Very recently, O2 announced in 2011 that by 2013 they would provide 15,000 free wifi hotspots, available to both O2 and non O2 customers. This maverick move by O2 would effectively break the market stronghold of current wifi providers BT and The Cloud, and paves the way for mobile VOIP calls to begin taking off. It is an example of a company moving away from the established norms of business, and moving this market from stability towards the edge of chaos as described by Wilkinson and Young (2002). Another example of an emerging firm attempting to enter this market has been made by Anyfi (a swedish company) that has developed and patented a protocol which effectively allows Anyfi to have accounts with ADSL providers so that a subscriber could make a mobile VOIP call at any point where the wifi coverage is sufficient (www.anyfi.com). This market for an agent acting between the wifi provider and the caller, has effectively created a new market in the route.

If the call is routed via the 3G network, then the issue is currently that 3G bandwidth has limited capacity and even with the use of efficient codecs, there may be insufficient capacity due to the growing use of different data traffic. In 2012, Ofcom will start the auction for licensing on the new 4G network; this will increase bandwidth from 3.6Mbs to 100Mbps for mobile connections and 1Gps for static links. This will massively increase the availability of bandwith for all data applications. At present, not all smartphones are compatible with 4G and although the US has already implemented 4G, only Android, HTC, Samsung Galayxy and RIM offer 4G compatible smartphones, although rumours suggest the iphone 5 may support 4G (www.wired.co.uk). Another destablising action has been made by a peripheral market player, Virgin mobile who state: "We are looking at way to converge data services. 3G networks are reaching a capacity crunch and wi-fi could offload traffic and offer a vastly superior overall throughput," said a Virgin Media spokesman (BBC News, 2010). Virgin are considering options to 3G bandwidth limitations including creating a network of wifi hotpspots.

C. Data stream transmission (Qos/DPI)

Due in part to the competition for bandwith and the mechanisms by which incumbent cellular operators charge calls, the control of the mobile VOIP data packets is important. In part, complementary technologies are required, but in part incumbent firms acting either alone, or in a collective manner can act to prevent this stage of the call from working well. The traditional telephone network assigns a dedicated circuit to a telephone call for its duration. Although this produces very reliable telephone calls, assigning a dedicated circuit to each telephone call makes very inefficient use of bandwidth. The public IP network was not designed for real-time packet transmission and typically does not reserve extra bandwidth to ensure that there are no transmission delays. Voice packets are intermingled with (low priority) data packets and both kinds of packets have to compete for bandwidth. Network congestion may lead to voice data signals being dropped altogether which causes clicking and popping sounds (Zheng, Zhang, and Xu, 2001). The technological problems result in consumer dissatisfaction and slow adoption of this technology.

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For mobile VOIP to work well for the consumer, there are a number of steps which need to be in place. Firstly, the voice signal needs to have been changed into a compressed data signal using an efficient codec as discussed in point A above which determines the amount of bandwith required for a transmission but secondly, the data packets need to be prioritized. The prioritization of data packets on a network is called QoS (quality of service), and by controlling QoS a network provider can either prioritize or prevent VOIP calling. To prevent transmission problems, VoIP packets must be given a high priority relative to other data packets. QoS is a technology which at present is going through an emerging stage; no accepted standard exists and several different mechanisms can be used (Cisco, 2009), as well as it providing a mechanism by which incumbent firms can delay the uptake of the new technology.

Another related technology which can affect transmission speeds is Deep Packet inspection; this is a technology which allows analysis of the content of the data stream to be identified; it can be used in anti-terrorism strategies and it could be used to enable companies to better route data traffic, or, to potentially to allow data providers to prioritise data traffic. In spite of its promising applications, however, again, DPI is still in its infancy when it comes to use by mobile operators. "Most mobile operators put DPI equipment in and turn it on; they don't manage [the traffic]. The DPI is purely to understand what is going on." However this is not the case for all network providers, as prioritising traffic is already occurring according to T Mobile, which states it is using DPI to "enhance customer experience" (www.royrubenstein.com). Although it is hard to determine if real time VOIP calling is being blocked by cellular operators, this is something which has previously happened in the US, with AT & Ts refusal to allow VOIP calls over their network (Tabini, 2010) (http://www.macworld.com/article/145994/2010/01/voip_3g.html). QoS and DPI can allow cellular providers to affect the speed of the transmission, and cellular providers also manage the volume of data packets per subscriber by capping their data usage. These actions are examples of incumbent firms acting both alone and collectively to prevent the disruptive change from being adopted in the marketplace.

D Gateway or Termination charges

The final stage of the call is the connection with the receiving device. The receiving device may set a charge to "accept the call"; for fixed lines this is not usually the case, but for a mobile phone receiving a call, the incumbent firms in this mature market have a strong influence on what is happening. The company that the recipient of the phone call subscribes to charges the initiating network a "termination" fee and this accounts for much of the income of mobile operators. For example in the UK, a Vodafone initiated phone-call to an O2 receiver will attract a fee of 4p from O2 to Vodafone; for smaller operators the termination charges can be prohibitive. In the UK the cellular network is dominated by 4 companies with approximately one quarter of the 2010 market each (Orange, 21.6%; Vodafone 21.4%; T-Mobile 23.4% and O2 25.2%), in addition to other smaller players such as 3. (Telecoms market research.com). In April 2010 T-Mobile and Orange merged, forming a single company, which by 2012 "Everything everywhere", with a predicted market share of 40-45% (Ofcom, 2011). The recent merger of T-Mobile and Orange means that they will collect 45% of all termination charges.

To avoid these termination charges, skype originally worked on only skype to skype calls, but has now derived a charging system for "Skype in" and "Skype out". OFCOM and the European Union have taken strong action on termination fees and a new ruling means that the charge from 2010 will be a maximum of 2.4p and this reduces to 0.7p in 2015. With the reduction in termination charges, the control of the market by incumbent firms will reduce.

Within this case study, the enabling technologies required for a mobile VOIP call have been delineated and described. Each of these technologies is both essential and complementary to the overall market offering of mobile VOIP calls. For each stage of the mobile VOIP call, the role of these technologies together with actions of incumbent and emerging firms has been described, and where information is available, inter-organizational networks or collective actions have been identified.

Discussion and Conclusions

Disruptive technologies are complex, and may not be recognized as such during their development or introduction into the market (Walsh et al, 2002; Afuah and Bahram 1995). The disruption could occur in markets outside the original technology, and the variables influencing the success or failure of the disruptive technology are many. A disruptive change may be the culmination of many enabling technologies that converge to provide what looks like a seamless commercial service to the consumer. By dissecting the stages and technologies required in the introduction of mobile VOIP calls, this paper has gone some way to illustrating the complexity of complementary technologies. Without a thorough understanding of the technologies at each stage, the market actions of both incumbent and emerging firms do not make sense.

Each one of these technologies and the firms involved in developing them is subject to the characteristics of new technologies; each may go through a period best described by Wilkinson and Young (2002) as the "edge of chaos" before a stable and accepted technology begins to dominate the market. Within the mobile VOIP "map", there are several of these "edge of chaos" points. Technologically there are several points: Handsets, Apps, SIP/ codecs / DPI/ QoS) all illustrate a lack of dominant standard. To control the end market, incumbent firms use both marketing strategies (pricing / regulations / termination charges) and technology strategies (control of wifi spots / DPI / QoS) to delay or even prevent the uptake of mobile VOIP which would cannibalise their revenue streams.

Each one of these emerging technologies and the "edge of chaos" points, brings with it the characteristics of either disruptive or incremental change, and may allow market entry for emerging firms (eg. Anyfi, skype). Table 2 summarizes these findings showing the critical points in the mobile VOIP "road-map" chain and noting, where information is available, the importance of inter-organizational networks in creating and sustaining this situation. In this table, where networks have enabled a step in the "map", these stages are marked with a ☼ and where collective action of network members has prevented the technology emerging, these are marked as □.

Point in mobile VOIP supply chain	Requirements / Barriers	Standards	The role of Inter-organizational networks	Instability of market indicated by:
A: Smartphone operating platform	Must be VOIP enabled or allow installation of mobile VOIP apps	3 or 4 current standards (see Table 2).	☼ The Open Handset alliance enabled Android.	☼ Nokia forming an alliance with Microsoft in 2011. App sales are restricted by platform operators
A: Codecs	Enabling technology	Several different standards	☼ Some as described in Table 2.	
A: SIP	Enabling technology	Emerging as the dominant standard although others exist	☼	
B: Wifi hotspots	Range and number, and little wifi sharing	No standard which allows roaming between wifi hotspots	☼ FON	O2 moves to offer free wifi to anyone. Anyfi developing a technology to allow roaming
B: 3G bandwidth	Lack of bandwith	4G may change the lack of bandwith	□ Though lack of bandwidth is a genuine concern, incumbent firms collectively act to prevent VOIP calls.	Virgin may open its wifi via cable network which would destablise this action.
C: DPI / QoS	Collective action by incumbent firms (?)	Several different technologies; no dominant standard as yet	□ Incumbent firms may use DPI and QoS to deprioritise VOIP calls thereby leading to burstiness and poor customer experience	
C: Pricing	Collective action by incumbent firms	n.a.	□ Pricing packages discourage consumers to consider VOI. All cellular network providers cap data transmission	
D: Termination charges	Collective action by incumbent firms	n.a.	□ Incumbent firms profits through termination charges delay VOIP uptake	OFCOM regulation and price reductions

Table 2. Summary of technologies and issues involved in bringing mVOIP to market

Table 2 illustrates both the enabling and the preventative roles that inter-organizational networks can play in the introduction or delay of a disruptive technology. Inter-organizational networks have enabled much of the technologies in the supply chain; codecs, SIP, Android, apps etc. However at this present moment in time, collective action from incumbent network providers has slowed the market through pricing, and collective action restricting data usage and delayed the disruptive change that will result from mobile VOIP. These similar strategies by incumbent firms can be likened to a virtual network as described by Olsen (1965). As each company maneuvers itself to be ready for the disruptive change that mobile VOIP will bring, each acts outside its current collective action, and the “edge of chaos” is reached. Not surprisingly, incumbent firms act collectively wherever possible to delay the disruptive technology which will cannibalize their revenue streams. However to best understand how these firms act, and control the new technology, it has been necessary to examine each stage of the technology; by controlling elements in the road map or by merging, acquiring or forming alliances with firms active at different stages of the road map, an incumbent market player can potentially control and remain dominant after the disruptive technology is established. This can be seen in the acquisition of Jajah, a VOIP app developer by O2; by acquiring the company, O2 has been able to control and limit the use of mobile VOIP to a subscriber based paying service. Not only does this limit the overall disruption in the current market, the customer perceives an additional benefit (cheaper international mobile calls) whilst the incumbent firm is controlling and preventing a wider uptake of the technology. Incumbent providers will need to develop a new revenue stream probably based on bandwidth and data usage rather than termination charges before wide stream adoption of mobile VOIP can occur unless something radical changes in the market place and a player can devise a revenue stream and acquire control or access to each point on the technology roadmap.

This paper has contributed to current knowledge by mapping an emerging disruptive technology and the role of inter-organizational networks at each point in its commercialization. However in such a fast moving situation, the study provides only a snapshot picture of the situation and is limited by the speed at which the technology and the market is changing. The potential disruption of mobile VOIP is of great important in terms of control of technology, and the generation of revenue streams and yet unless a new market mechanism is created, the consumer may be unaware of the disruption of this technology. It is possible that incumbent mobile network providers will switch to using only mobile VOIP technology. Only if the current market structure is destroyed will this potentially radical technology appear to be disruptive to the consumer. If the incumbent firms take control of the enabling technologies or firms supplying these, consumers may see little change, thereby hiding what has been a radical disruptive technological change. Alternatively incumbent mobile network providers might be pushed out by a new pricing or control structure; will the proliferation of free wifi spots enable consumers to make free mobile VOIP calls and if so, will a new business model be required? Maybe future consumers will pay nothing for phone calls, but more for handsets? The commercialization and business models for this technology are not yet established, and predicting which will emerge, and how it will be controlled requires more than just a technology roadmap; but a market-technology roadmap.

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