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Future Scenarios for Local Area Access: Industry Structure and Access Fragmentation

Timo Smura
Dep. of Communications and Networking
TKK Helsinki University of Technology
Espoo, Finland
timo.smura@tkk.fi

Antti Sorri
Nokia Research Center
Nokia Oyj
Helsinki, Finland
antti.sorri@nokia.com

Abstract— **Indoor deployments of wireless access points will likely be required to fulfill the future traffic capacity requirements. Considerable uncertainty exists, however, about the technologies utilized to provide local area access, as well as the roles of different actors in the value network providing mobile services. We apply Schoemaker's scenario planning method to identify and analyze the key uncertainties and to construct four alternative and plausible future scenarios having different implications to local area access technologies and business models. The results are valuable in designing wireless technologies and standards for the future, as well as in pointing out the role of local area access provisioning as a potential control point in the mobile services business.**

Keywords-mobile; local area networks; scenario planning; value network

I. INTRODUCTION

The volume of wireless data traffic is growing exponentially in many developed markets. In Finland the volume of packet-switched data transferred in mobile operators' networks increased five-fold in 2007 to around 500 terabytes (TB), from 100 TB in 2006 and 34 TB in 2005[1] [1]. The growth, currently driven by laptop users [2] is expected to continue globally. Mobile network manufacturer Nokia Siemens Networks expects mobile data traffic to grow 300-fold between 2009 and 2015, with just a 3-fold growth in mobile data revenues [3]. The volume of mobile data traffic will clearly dominate relative to mobile voice traffic.

Mobile data traffic growth will require changes in the network deployment strategies of mobile network operators as well as in the business models of the industry. As data traffic surpasses voice traffic, the focus of network investments and capacity improvements will also shift from voice to data. Increasing capacity demands are partly served by the higher data rates of new wide area cellular technologies like HSPA (High Speed Packet Access) and LTE (Long Term Evolution) developed by 3GPP (3rd Generation Partnership Project), but the deployment density of cellular base stations will also have to increase. Indoor deployments will likely be required to provide the required data rates in the areas where they are needed (see e.g. [4]).

Base stations located outdoors provide cellular coverage and capacity for wide area networks. This coverage is used by devices located both indoors and outdoors. These networks utilize technologies based on specifications from 3GPP and 3GPP2 in Europe and in the U.S. respectively. Alternative technologies such as WiMAX are also expected to be utilized in some markets.

For local area access network deployments two main technological alternatives currently exist. Wireless Local Area Networks (WLANs) based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards have become widespread throughout offices and households. These WLANs utilize unlicensed spectrum and extend existing fixed broadband connections wirelessly to mobile and portable devices. Femtocells offer an alternative based on specifications from 3GPP and 3GPP2. Relying on licensed spectrum, femtocells are emerging as an option for mobile operators to extend the coverage and capacity of wide area cellular networks in to indoor locations.

Wide area networks, WLANs, and femtocells are substitutes for one another for many devices located indoors which require wireless connectivity and Internet access. Considerable uncertainty exists about which of the alternative technologies will be deployed, where they will be deployed, for which types of services and applications, and by whom.

A systematic scenario planning method is used in this paper to identify and analyze the key sources of uncertainty affecting the local area technologies and business models. The second section of this paper presents the scenario planning method, and in the third we present the phases of our scenario planning process and the results achieved. The final section summarizes the paper and discusses the implications of the results to local area access development.

II. SCENARIO PLANNING METHOD

Scenario planning is a commonly used tool for long range business planning and decision making under conditions of substantial uncertainty. Modern scenario techniques have their roots in the 1950s war game simulations at the Rand Corporation [5]. In the early 1970s, the method was adopted by businesses for strategic decision making, with Royal Dutch/Shell being one of the early proponents using the method to prepare for the 1973 oil crisis [6].

[1] In comparison, the volume of mobile originated calls in 2007 was 13447.1 million minutes, i.e. approximately 1600 TB assuming a bit rate of 16kbps (1 TB = 10^{12} bytes).

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More recently, scenario planning has gained popularity as a tool for managing emerging technologies in the rapidly evolving ICT industry. Schoemaker & Mavaddat [7] demonstrate the use of the method by studying the potential impact of Internet on large newspaper companies. Karlson et al. [8] apply scenario planning to the wireless industry, and construct four scenarios describing how the wireless world might evolve between 2003 and 2015. Heikkinen uses scenarios to study mobile peer-to-peer service usage [9] and mobile peer-to-peer session initiation protocol (P2PSIP) services [10].

Scenario planning has developed in several different directions over the intervening decades. This has resulted in apparent contradictions and confusion over related definitions, principles, and methods. For an overview, classification, and comparison of the main schools of scenario planning methodologies see [11]. In our work we found the scenario planning method of Schoemaker [5, 7, 12, 13] well suited for our needs. Schoemaker [5] defines scenarios broadly as "focused descriptions of fundamentally different futures presented in coherent script-like or narrative fashion." Scenarios should not be treated as forecasts, but rather as means for bounding and understanding future uncertainties. According to Schoemaker [13] scenario planning should aim at challenging the prevailing mind-set and stimulating decision makers to consider changes they would otherwise ignore. The process for developing scenarios includes the following ten steps (Table I).

TABLE I. STEPS IN SCENARIO CONSTRUCTION [7]

#	Step
1	Define the issues you wish to understand better in terms of time frame, scope, and decision variables.
2	Identify the major stakeholders or actors who would have an interest in these issues, and their current roles, interests, and power positions.
3	Identify and study the main forces that are shaping the future within the scope, covering the social, technological, economic, environmental, and political domains.
4	Identify trends or predetermined elements that will affect the issues of interest from the list of main forces.
5	Identify key uncertainties (forces deemed important whose outcomes are not very predictable) from the list of main forces. Examine how they interrelate.
6	Select the two most important key uncertainties, and cross their outcomes in a matrix. Add suitable outcomes from other key uncertainties, as well as trends and pretermined elements to all scenarios.
7	Assess the internal consistency and plausibility of the initial scenarios, revise.
8	Assess how the key stakeholders might behave in the revised scenarios.
9	See if certain interactions can be formalized in a quantitative model.
10	Reassess the uncertainty ranges of the main variables of interest, and express more quantitatively how each variable looks under different scenarios.

The focus of this paper is on the construction and qualitative description of scenarios. Quantitative modeling (Steps 9-10) is not carried out.

III. SCENARIO PLANNING FOR LOCAL AREA ACCESS

A. *Time frame, scope, and stakeholders*

We define our issue of interest with the following broad research question: "How will network connectivity for devices located indoors be provided in the future?" Within this wide topic area we are interested in the following subtopics:

- roles of different actors, including operators, device vendors, end-users, and site owners;
- network architecture and deployment strategy;
- radio technologies utilized.

The time frame for this study is defined as approximately ten years, focusing on developments from the present through 2015 or 2020. The scope of the study is intentionally kept very broad in order to reach a holistic view of the topic area. The scope is geographically global and covers all types of indoor locations including residential homes, office buildings, and other public and private venues. All types of devices requiring wireless connectivity (not just mobile phones) are within the scope of the study.

We identify a number of stakeholder roles that could have an interest in the future evolution of local area access. This is illustrated in Fig. 1. The roles are represented by ellipses, and one actor (i.e. firm) may assume many roles simultaneously.

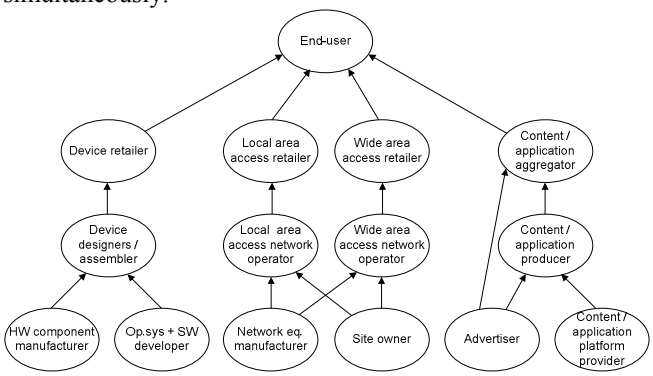

Figure 1. Stakeholder roles in the mobile services value network.

The value network of Fig. 1 includes three value chains, separately for devices, access, and content / applications, comprising the essential technical components of mobile service systems [14]. In the device value chain, four essential roles are identified: device retailers, device designers/assemblers, hardware (HW) component manufacturers, and operating system and software (SW) developers. In the access provisioning value chain, separate roles for retailers and network operators of both wide area and local area accesses are identified, together with network equipment manufacturers and site owners. Finally, the content / application provisioning value chain comprises of aggregators, producers, and platform providers for the content and applications, as well as advertisers.

Established mobile operators such as Vodafone and Verizon Wireless, as well as mobile device vendors like Nokia, Samsung, and Apple currently hold strong positions in the value network, together with established network

equipment manufacturers like Ericsson and Nokia Siemens Networks. Mobile operators naturally take the wide area network operator and access retailer roles, but have also extended their power to device retailer and content / application retailer roles, by bundling devices with access subscriptions and by pre-configuring these devices to use the operators' own portals as the preferred gateway to mobile content and applications. An example of this is Vodafone's use of Vodafone Live.

Large device vendors typically assume the roles of device designer / assembler and operating system + SW developer. Device vendors have recently started to expand their business into the content / application value chain taking the producer and aggregator roles there. Nokia's Ovi services are an example. Apple's strategy of taking both device (iPod and iPhone) and content / application provisioning (iTunes, AppStore) related roles are another example. This may decrease the power of established mobile operators in the value network.

Finally, large Internet and software-based players like Google and Microsoft are showing increasing interest in gaining more control over the emerging mobile services market. Google already has many roles in the content / application provisioning value chain. It is expanding its business to device operating systems and software (Google Android, Google mobile services). Google has also shown interest in at least influencing the terms in which spectrum is allocated for future access networks (e.g. U.S. "White Spaces" and 700 MHz auctions).

In conclusion, many firms with different backgrounds and assets have interest in taking and controlling the essential "gatekeeper roles" (see e.g. [15]) or "control points" in the mobile services value network. For our analysis this raises two important areas where better understanding is required:

- How does the role and nature of local area access depend on which of the actors are in control of the mobile services value network?
- Is local area access provisioning a potential "gatekeeper role" in the future mobile services value network?

B. *Identifying the main forces*

In order to reach a broad view of the trends and uncertainties affecting our issue of interest we organized a half-day workshop with 15 topic area experts. The experts represented mobile device vendor Nokia and mobile network vendor Nokia-Siemens Networks. The workshop included business developers, technology experts, as well as regulatory experts.

The workshop was structured into four brainstorming sessions focusing on 1) political / regulatory, 2) economic / industry, 3) social, and 4) technological forces respectively. The brainstorming sessions followed a form of combined individual thinking and group discussion. The participants were given time to list their ideas and opinions in each session. Then, participants were given time to introduce and explain their inputs, stimulating group discussion on each of the identified forces. During the presentation of individual forces similar notes were grouped together. Each session ended with evaluation and prioritization of these grouped notes. Each group of notes was evaluated through group discussion on the scale of 1 - 4 in terms of both the importance and uncertainty of the underlying force.

As a result from the workshop, a total of 182 forces affecting the future of local area access had been identified, grouped, and evaluated. These constitute the raw data for the scenario construction.

C. *Key Trends and Uncertainties*

Based on the data we collected, we have identified seven major trends likely to have an effect on the future of local area access provisioning (Table II).

TABLE II. SEVEN KEY TRENDS

Id (Class)	Trend
T1 (Tech.)	Devices' capabilities and performance improve
T2 (Soc.)	Wireless traffic will increase
T3 (Tech.)	Number of base stations / access points increases
T4 (Soc. / Tech.)	Importance of indoor wireless access increases
T5 (Econ.)	Role of developing countries increasing
T6 (Tech.)	Operational costs will dominate over hardware costs
T7 (Soc.)	Wireless emissions scare people

T_1: Mobile and portable devices are constantly evolving and becoming more powerful and useful as processing power, memory sizes, connectivity options, and data rates keep improving. Devices will become more intelligent and cognitive as a result. New features like cameras, global positioning system (GPS) receivers, and even video projectors will extend the ways in which the devices can be used. Energy consumption and battery power limitations establish a boundary for these developments.

T_2, T_3: People already prefer to use their devices without connecting cables. This will increase the volume of wireless traffic. More wireless base stations and access points are required to meet capacity demands.

T_4: The majority of wireless traffic and operator revenue is already originated by users and devices in indoor locations, and this share will increase in the future. Therefore, as the number of access points increases (T_3), they are likely to be deployed also indoors. This may cause interference problems between access points.

T_5: The role of developing countries, particularly China and India, will increase both politically and economically. This may also have an affect on the positions of technology alternatives for local area access (see also uncertainty U_6).

T_6: Increasing volumes of base stations, access points, and connected devices will drive down the cost of hardware components. Operational, administration, and maintenance costs of wireless networks will dominate relative to hardware costs.

T_7: Concerns about the health effects of wireless radiation will continue as the number of wirelessly connected devices keeps increasing. This will somewhat limit the willingness of people to accept wireless access points in their homes and offices.

We also identified six key uncertainties which have an effect on possible outcomes. The uncertainties and their correlations are presented in Table III.

TABLE III. SIX KEY UNCERTAINTIES AND THEIR CORRELATIONS

Id (Class)	Key uncertainty	Possible outcomes
U_1 (Econ.)	Industry structure	1) Vertical 2) Horizontal
U_2 (Tech.)	Competition between technology substitutes	1) Remain low 2) Increase strongly
U_3 (Reg.)	Spectrum policy and regulation	1) Harmonized 2) Liberalized
U_4 (Reg.)	Role of unlicensed spectrum	1) Limited 2) Significant
U_5 (Tech. / soc.)	Number of connected devices	1) Grow modestly 2) Explode
U_6 (Econ.)	Role of emerging markets in affecting technology choices	1) Minimal 2) Significant locally 3) Significant world-wide

Correlations between key uncertainties

	U_1	U_2	U_3	U_4	U_5	U_6
U_1	1	+	+	+	0	0
U_2		1	++	+	0	+
U_3			1	+	0	0
U_4				1	++	0
U_5					1	0
U_6						1

U_1: The mobile industry (and the business models within) may develop towards either horizontal and distributed or vertical and centralized structures (see also next subsection).

U_2: Competition between technology substitutes may remain low or increase substantially. In the former case, wide area and femtocell technologies from 3GPP will have a strong position in the market, with IEEE 802.11 WLANs complementing these in private local area networks. In the latter case non-3GPP standards and proprietary technologies will gain significant market share also in public access provisioning.

U_3: In spectrum regulation two opposing forces are competing. On one hand, there is a push towards larger degree of liberalization and technology neutrality to foster competition between technologies and operators by allowing easier entry to markets. On the other hand, established players are lobbying for geographical and technological harmonization, claiming benefits from global services and efficiency in manufacturing.

U_4: Another spectrum uncertainty is related to the role of unlicensed spectrum affecting the technology choices of network and device vendors. In a limited role unlicensed spectrum is not used use for public or commercial access provisioning. This might be due to limited guarantees against interference and limited spectrum availability resulting in high investment risks. Another possibility is that the role of unlicensed spectrum will become significant and commercial services in unlicensed band gain significant market shares also in public access provisioning. This may require that interference issues can be dealt with technically or unlicensed spectrum becomes available to meet the need.

U_5: The number of wirelessly connected devices is expected to grow during the following years, but the pace and timing of the growth is highly uncertain. In case of modest growth, the variety of devices will stay on the level of around 3-5 connected devices per person. In the case of explosion in number of devices, the number will increase to 10s – 100s of devices per person, and include e.g. large amounts of wireless sensors.

U_6: The sixth key uncertainty is the role of emerging markets in affecting technology choices, particularly China and India. In the case of a minimal role, these countries will adopt and use the standards and technologies developed mainly by European and U.S. companies and organizations. Where the countries have a significant local role they will adopt their own locally developed technologies. If they have a significant world-wide role these technologies will be used globally.

D. Scenario construction and assessment

The next step was to find the two most important, sufficiently uncorrelated key uncertainties, and to cross their outcomes in a matrix. After a number of iterations, this was achieved by selecting U_1 and a combination of U_2, U_3, and U_4 as the two dimensions in our scenario matrix.

The y-axis of our scenario matrix comprises the industry structure in terms of the level of vertical integration in access and content / applications provisioning. We define a vertical industry structure as one in which network access and content and applications are provided by the same company, bundled, and sold as packages to end customers. The customers make a contract with a single company that satisfies their needs with a complete portfolio containing traditional voice call and SMS applications as well as more advanced data and Internet applications. Bundling leads to a few large players dominating the market and to a lower level of competition in the content / applications market.

In a horizontal industry structure content and applications are offered individually from access without bundling. Different service components are provided by different players and customers can purchase content, applications, and devices separately from access. From the customer point-of-view, it is easier to switch between access and content / application providers, leading to a higher level of competition in both these markets.

The x-axis of the matrix is defined as the level of technological fragmentation in the access market. In the case of integrated access few operators (~3-5) hold the essential spectrum licenses for providing public services. Licenses are granted and restricted to "technology families", like IMT-2000 and IMT-Advanced for long periods. The number of alternative access technologies remains low and the same technologies are used to serve both outdoor and indoor locations. Unlicensed spectrum is limited to private use by households and businesses. The general level of competition between access technologies and operators is comparatively low.

In the fragmented access case the number of alternative access operators and technologies and the resulting competition in the access market is high. Usage of licensed

spectrum becomes more flexible, as technology neutrality, local licenses, spectrum trading, and more dynamic use of spectrum are required by the regulator as means to induce competition. The role of unlicensed spectrum becomes more significant also in public service offerings.

After deciding on the axes we defined one scenario for each of the cells in our scenario matrix. As the two axes do not cover all possible uncertainties regarding the future it would be possible to define more than one scenario for each cell. We opted to construct one plausible scenario for each cell, as depicted in Fig. 2.

In Fig. 2 we have provided simple illustrations for the scenarios, pointing out the differences between access technologies and their providers as well as content / applications and their providers in each of the scenarios. Wide area (WA) and local area (LA) technologies and four exemplary content / application types (voice, e-mail, maps, and music) are depicted as ellipses. The actors responsible for providing each of these are depicted as boxes. In the case of a single player controlling multiple access technologies or content / application types multiple ellipses are located within one box.

3.4.1. Pick-n-mix – Internet rules: The first scenario is a combination of horizontal industry structure and fragmented access. In this scenario the level of competition is high in both the access and content / application markets and customers can (and have to) choose between many alternative providers. This results mainly from regulator's push towards separation of access and content / application businesses. Wide area and local area access are provided separately by different players. There are many network providers with different technology strategies in both markets. The players use standard and proprietary technologies for both licensed and unlicensed bands. Users have to make many choices between different accesses and content / application options, which results in many contracts and business relationships. Cognitive and intelligent devices can be used to make these choices dynamically on behalf of the user by e.g. switching between networks according to users preferences. New opportunities exist for independent billing services like credit card companies and PayPal.

3.4.2. Complete bundles – operator rules: The second scenario is in many ways an opposite of the first one. Here, the industry structure is vertical and competition takes place between bundle offerings from a few large mobile operators that have been able to utilize and extend their control over the access networks through to the content and application markets. Users prefer convenience and ease-of-use over a low price and choose between similar bundles of devices, accesses (both wide area and local area), content and applications controlled by the incumbents. Although the operators are controlling and billing for the services they do not need to produce them all by themselves but will also rely on the offerings of selected partners in the media and Internet service industry. Barriers to entry for network vendor and operator markets are high as globally harmonized standards and spectrum drive standardization on a few dominant technologies. Unlicensed spectrum use is mostly limited to private LANs and also there the operator-managed networks dominate over self-managed installations.

3.4.3. Operators as bitpipes: The third scenario is a combination of horizontal industry structure and integrated access. Regulatory actions have resulted in separation of access and content / application provisioning, which results in users buying flat-rate data plans from the operators and paying for content and applications separately. In contrast to scenario 1 the access markets are still controlled by a small number of established operators utilizing globally harmonized spectrum and a few dominant standard technologies. Access operators are focused on providing high quality connectivity efficiently and offering bundles of wide area and local area access to the customers. The level of

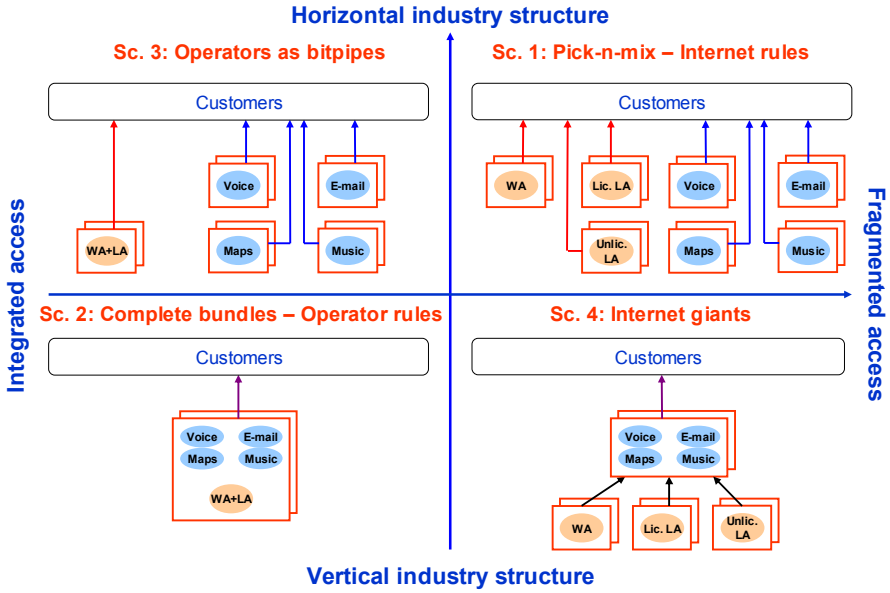

Figure 2. Scenario matrix.

competition in the access markets is comparatively low in contrast to the content / application markets where the entry barriers are lower and users can choose and switch between providers more easily.

3.4.4. Internet giants: The fourth scenario results from a combination of vertical industry structure and fragmented access. Instead of the mobile operators, large "Internet giants" (e.g. Google or Microsoft) have extended their power over applications and content to the access markets. Competition is fierce between many access providers and technologies, and none of the access providers have the scale or influence approaching that of the Internet giants – putting the giants in control. The Internet giants effectively own the customers and charge for the service bundles directly or indirectly, possibly through advertisement-based business models. Operators are not very visible to users as access is bundled within the service offerings and sold to / via the Internet giants on a wholesale or roaming basis. Wide area and local area access is typically provided by different players. Liberalized spectrum licensing and unlicensed spectrum give opportunities to new entrants to serve smaller geographical areas and market segments.

E. Stakeholder analysis

As the final step in our scenario construction, we examined the scenarios from the viewpoints of the different stakeholders. Inspired by Christensen et al. [16], we depicted the distribution of value between actors in the value network as shown in Fig. 3.

From the point of view of wide area network operators who are currently in strong positions in the value network, scenarios 1 and 4 are clearly the most troublesome. Revenues from access are diminished because of the fragmented access markets. Revenues from content and applications are also out of reach in both of these scenarios. Scenario 3 is somewhat more profitable, as the WA network operators are able to control the LA access and benefit from the limited competition in the access markets in general. Scenario 2, in which WA operators are able to capture a significant share of the content / application revenues as well appears to be the most lucrative, although the total size of the application / content market might be smaller compared to the other scenarios.

For content and application producers in general, scenario 2 is the least profitable, as the established operators own the customer and use this position to take their share from the revenues. Nevertheless, operators may provide a gateway to wide markets for small content and application producers. Scenarios 1 and 3 are somewhat better as the producers can also take on the retailer role and have direct relationships with the customers. Finally, for large "Internet Giants" it might be possible to take a dominant role in the value network making access network operators invisible to the customers (Scenario 4). This would allow them to collect most of the revenue at the expense of the other actors.

From the point of view of established device manufacturers, scenario 3 seems to be the most lucrative one. The number of access technologies to be supported is lower here and entry to the device market is more difficult. Mobile operator's power outside the access markets is also limited giving device vendors a possibility of direct customer relationships and to expand their business into the content and applications markets. Vertical industry structures (scenarios 2 and 4) limit control over sales channels and decrease the device vendors' brand value. In the fragmented access scenarios (1 and 4) devices are more complex because many access technologies have to be supported. Competition

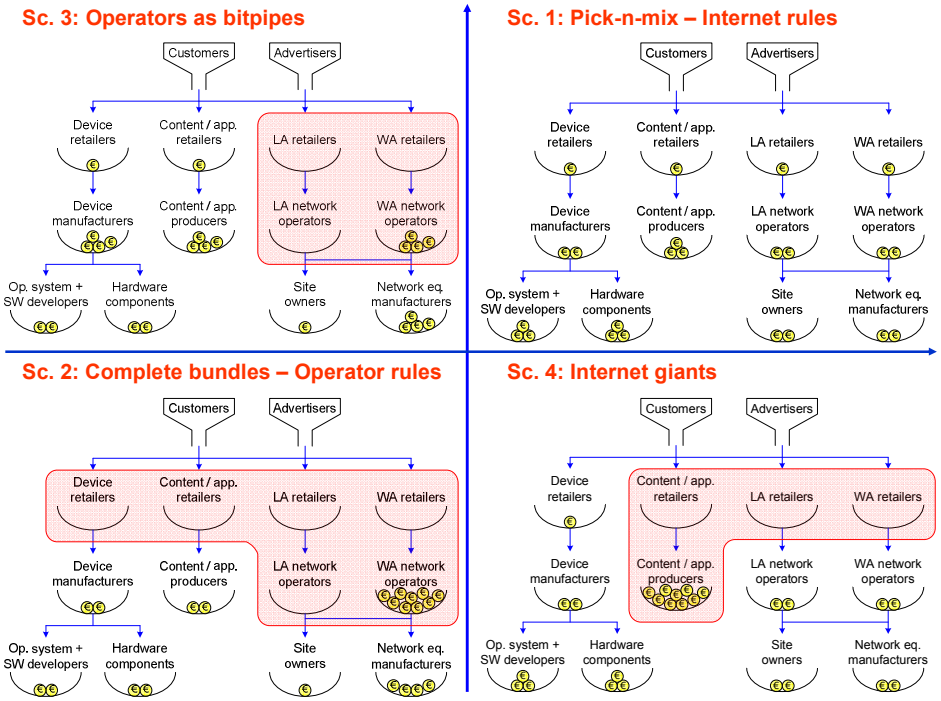

Figure 3. Distribution of value between actors in different scenarios.

is intense and a larger share of the device revenue flows to the HW component manufacturers and SW developers.

For established network equipment manufacturers the integrated access scenarios (2 and 3) are more profitable as competition is comparatively low. Fragmented access scenarios (1 and 4) are more difficult to handle as there are more customers and more technologies to manage and competition is more intense. On the other hand, for site owners the fragmented access scenarios are more profitable as their negotiation power increases due to higher level of competition between access providers. Fragmented access may also enable more tailored solution offerings, where the site owner's needs are best served.

IV. Summary and Discussion

The scenarios presented act as a basis for discussing the future role of local area access within the mobile services business. Firstly, the scenarios can be used as a reference when developing technologies and standards for local area networks, to identify bottlenecks of current systems as well as key features required to outperform competing technologies in each of the future scenarios. Secondly, the scenarios point out local area access provisioning as a potential "gatekeeper role" in the mobile services business more generally.

The success of alternative local area access technologies will depend on how well their characteristics and features will match the requirements of the future environment. In the integrated access scenarios (2 and 3) standardized technologies that offer good performance and can scale to different use cases and environments are preferred. Local area networks are deployed and maintained by large access network operators who integrate them tightly into their existing network infrastructure in order to utilize economies of scale in lowering the operational costs.

The fragmented access scenarios require somewhat different characteristics from local area access technologies. The access providers may be small and local, and lack the technical expertise for maintaining complex systems. Therefore, installation and maintenance of the networks should be made as simple as possible. Fragmented access may lead to complex deployments where several radio technologies are operating in the same frequency bands including unlicensed bands. This requires that radio technologies have sufficient self-organization and cognitive capabilities to operate efficiently in heterogeneous radio environments.

Many of the forces identified in our work point out the increasing importance of indoor wireless access networks in the future mobile environment. As a large share of mobile revenues is generated by devices and users located indoors, focusing on local area access might allow new players to enter the access markets and to capture a large share of revenue. Therefore, instead of planning technologies to succeed in each of the potential futures, technology could rather be seen as the means to reach a desired scenario. As none of our scenarios seems to present a "win-win" situation for all the stakeholders in the value network different players are expected to push regulators and standards organizations into different directions regarding local area access development.

In this paper, we have not provided quantitative analysis or modeling of the variables and their interactions (see steps 9 and 10 in Schoemaker's scenario planning process, Table I). Future work will include utilizing system dynamics methods for modeling the interdependencies of the individual trends and uncertainties and their combined effect on the realization of the alternative scenarios, as well as the resulting distribution of value within the value network.

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