Shaping Technology as a Means of Transforming Society: The Case of the GSM Standard for Mobile Telecommunication

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Something is happening in the field of knowledge generation and technological development. The phenomenon has been described in the sociology of science and technology as the emergence of a new mode of knowledge production (Gibbons *et al.*, 1994). Studies in industrial sociology and in economics address the development in a more normative way arguing that global competition forces speed up the generation and utilisation of new knowledge and products, in brief: of the innovation process (e.g. Lundvall and Borrás, 1997). It has also been argued that particularly innovative ways of combining existing techniques, technological strategies and distributed bodies of knowledge are likely to open up promising fields of application and new markets. Moreover, there is a consensus that both tendencies result in an increase in pressure on the established societal institutions of knowledge and technology production to adapt to the new and ever-changing conditions. The consequences seem to be evident: industry and academia have to establish new forms of co-operation and a new division of labour to remain, or to become, competitive.

Innovation networks are often quoted as an efficient way of coping with these problems. Like social networks in general (see Powell, 1990), an innovation network is usually conceptualised as an alternative means of co-ordinating actions, different from both markets and hierarchies. In networks participants follow their individual interests and strategies. But they do so in a collaborative manner: their actions are coupled in such a way that every actor's success depends on his partners in the network also being successful. In both sociological and economic theories the relations within social networks are characterised as being informal, rather than formalised and largely based on personal communication. The exchange of information is reciprocal. And all of this is facili-

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tated and stabilised by the presence of a great deal of trust. Correspondingly, in a variety of studies (see DeBresson & Amesse, 1991) the major advantage of networks in innovation processes appears to be twofold. They are more flexible and more likely to stimulate horizontal communication and interchange than hierarchies are. In addition they are more suitable for operations directed towards an uncertain future than markets are.

At first sight this seems to be quite clear and convincing. But there have also been reports of problems with this kind of co-ordination. One has been named the "Lock-in problem". To cut a long story short: there is no intrinsic need for networks to open up to new and unexpected demands or – even worse – to adapt to changes in the environment of a network. There are examples that the very opposite can be true. For instance scholars who studied the old German coal and steel area of the *Ruhrgebiet*, demonstrated that it was precisely those stable networks put into place by economical, political and other actors which for a long time prevented inevitable structural changes in this region being implemented (Grabher, 1993).

In the following section of this paper I would like to call attention to a number of theoretical and methodological questions raised by these contradictory findings, namely to problems that seem to have been somewhat underestimated in mainstream network analysis in industrial sociology and economics. Helpful though the network concept it uses is in overcoming the limitations of the linear model which explains innovation as a sequence of separate phases of basic research, applied research and diffusion, its usage tends to give answers where questions should be raised. In order to determine the importance of networks in and for the dynamics of innovation processes and its results, a much more differentiated view on the matter is needed. I will argue for a broadening of the analytic perspective, which takes the generation of innovation networks and the variety of their different elements into account. The article will close with a few remarks concerning the political relevance of R&D projects this perspective can reveal.

Shift of Analytical Perspectives: From Networks to Network Formation

Taking innovation networks as a fait accompli, one can treat them as a particular means of exchanging different kinds of resources. And there is no need to pay much attention to the peculiarities of these resources which are, besides money, mainly different kinds and forms of knowledge. Based on such a conceptualisation, research is likely to focus merely on the so-called social side of the matter, i.e. on the participants, their communication, on trust, power relations and the like. These are, to be sure, important features that – somehow – influence the outcomes of innovation processes. But to determine the dynamics of innovation one should not be limited to such "con-textual" issues, but explicitly take into consideration the "text" of the processes, in other words: to a first approximation, what the participants' communication is about. For an examination of the dynamics of innovation and the typical obstacles which might hamper it, one should take this as a point of departure for analysis and, then, concentrate less on the net*works* themselves than on net*working*. In brief: we should focus on the conditions for and ways of joining actors and other elements together (see Häusler *et al.*, 1994), and especially on the criteria which guide such actions.

Innovation networks are what Gibbons *et al.* called transient organisational forms: "people come together in temporary work teams and networks which dissolve when a problem is solved or redefined" (Gibbons *et al.*, 1994: 6). This is to say that innovation networks, as opposed to organisations, are usually not kept "in stock" as a kind of institutional receptacle which exists and can be implemented when needed. They emerge and exist from practice. For analytic purposes one should therefore conceptualise innovation networks not as entities but as processes. Within these processes heterogeneous individual and organisational actors – such as scientists and business people, or industrial firms and research institutes – and problems, model solutions, knowledge, devices and different kinds of resources are configured to reach specific goals. If one looks at it this way, elements of the emerging configurations are not only human beings and organisations but also artefacts, theories et cetera. All these are components of the emerging configurations. Without these the others would not exist. They are fundamentally *sociotechnical* configurations.

It is the actor-network theory (ANT) in particular, which stresses this point. It argues that you overlook important features of (not only) innovation processes if you concentrate exclusively on people or organisations and their behaviour (Callon, 1987; Latour, 1992; Law & Hassard, 1999). The conclusion is well known. The ANT treats artefacts as actors (or actants) which actively participate in network formation. It would go beyond the scope of this paper to enter into discussion provoked by this plea for a symmetrical treatment of human, natural and technical "actants" (cf. e.g. the critique of Collins & Yearley and Callon's and Latour's reply in Pickering, 1992). I assume that it is people and organisations who bring such configurations to life. But they do so by networking, by associating with one another and with other elements, like those just mentioned. After all, they *are* very influential in the outcome. Take, for instance, a collaborative R&D project in which actors with different expertise join together to work as partners. One can describe their collaboration solely in terms of a network of individuals and organisations. If you adhere to this point of view and treat the network's particular purpose and its other elements as a black box, there is little else to do but to debate on the actors' general motives for getting together and on their various modes of communication. Fair enough. But to move beyond the somewhat helpless statement that technical innovations need to be "socially embedded" one needs to argue, I would think, more specifically. And this can only be done by opening that black box and determining more precisely what the issues are which the partners (are going to) work on. To do this, you may go along with the ANT's maxim: Follow the actor!

Typical questions to be addressed by project managers at the very *outset* of what might eventually end up as an innovation network are, for example, "What must an interesting project partner be able to perform? What kinds of instruments and other devices do we need? And where do we find all this?" The answer to these types of questions is obviously very closely linked to the specifications of technical and other tasks. In more general terms: the very definition of what is problematic in and for an R&D project is, at the same time, a specification of the competence needed and, as such, an approximate description of potential contributors. Once enrolled in a network-like collaboration, these contributors may bring about a reformulation of the initial problem-definition, highlighting other aspects and probably drawing attention to other instruments and further experts that need to be enrolled. One can conclude that specifying a problem usually also means, indirectly though, specifying potential partners, concepts and artefacts that can contribute to the solution. And the specific configuration of these elements in turn stabilises a problem-definition at a given point in time. Thus specifying R&D problems and networking actors and other elements may well coincide (as two sides of the same coin). Taking this into account, knowledge production and innovation do not seem to just "take place" in networks, but the networking of actors, problems, concepts and artefacts appears to be the means of producing knowledge and of pushing forward innovation.

An interesting conclusion that can be drawn from this outlined conceptualisation links up with the question of social consequences of technology.[1] If networking actors, knowledge, and artefacts is an integral part of developing a new technology, the resulting configurations must be considered to be one product of this development work. A product of reasonably intriguing quality: the configurations that are established during a successful R&D-project need not disappear altogether when the project is finished. Certain parts may go on to form the nucleus of new social or even societal structures. New forms of work-organisation may come into being with the implementation of new machinery. New industries may evolve to elaborate and commercialise findings made in joint research projects. Or new patterns of collaboration between science, industry and public administration in the constellation Etzkowitz (1990) named the Triple Helix of modern societies may emerge as a result of successful R&D programmes. I would like to argue that there is no reason for understanding such outcomes merely as social consequences of a technology in use. They are not simply effects that appear once the technologists' job is *done*. Instead, developing technology should be considered as means to intentionally transform social reality by building up sociotechnical configurations. The rest of this paper tries to present some empirical evidence to support this hypotheses.

The Standardisation of the Global System for Mobile Communications (GSM) [2]

At a meeting in Vienna in June 1982 the *Conférence Européen de Postes et Télécommunication* (CEPT), then responsible for the cross-border harmonisation of telecommunication services in Europe, decided to form a study group, the *Groupe Spécial Mobile* (GSM). This group was set up to work out specifications for a pan-European cellular communication system for the 900 MHz frequency band which had recently been allocated to land mobile use. The idea behind this decision was to create, for the first time, a system that would end the traditional European fragmentation and incompatibility in the mobile field. (Haug, 1992) In the following ten years a concerted effort was made by virtually all the competent political and economic bodies in Europe to develop a radio telecommunication service from the very first seeds of an idea right through to specifying a standard and implementing it (see Mouly & Pautet, 1992; Haug, 1990).

Up to the early 1990s the cross-border use of a mobile telephone was hardly possible in Europe. An NMT-phone, for instance, a mobile station complying with the Nordic Mobile Telephone Standard could be used in all the Scandinavian countries, because they had the appropriate infrastructure, but not in other countries which had either modified versions of NMT or completely different systems. In the 1980s more than half a dozen different radiotelephone systems were (and some of them still are) in use in Western Europe. The consequence of this large number of different technologies was a highly fragmented market. This was the major obstacle preventing a massive spread of this mode of communication. Due to the relatively small national markets the high costs for R&D and for the infrastructure resulted in extremely high prices for end-users. Therefore mobile telephony was a service only offered in niche-markets to very well-off and mostly commercial users.

GSM Standardisation and Emerging EC Telecommunication Policy

Though the GSM development was from the outset a project in and for ”CEPT Europe”, that is, not only for members of the European Communities (EC), the Commission in Brussels greatly influenced its direction and speed from the second half of the 1980s onward. This was far from being self-evident because only a few years earlier Community institutions simply did not exist as an actor in the telecom-sector. This was still an exclusive domain for the mostly state-owned operators, national authorities and international associations of those like the CEPT, and, to some extent, the producers of components. Not until December 1977 were general problems of a pan-European telecommunication policy and a possible co-operation between the Commission and CEPT discussed at a meeting of the Community's Postal and Telecommunications Cabinet Ministers and the Commission for the first time. An important early step towards a genuinely European telecom-policy were three recommendations to the Council, submitted by the Commission in September 1980. They aimed at harmonising the telecommunication sector and establishing a community-wide single market for end-user equipment. But it took four more years before the Council adopted these recommendations, though in a slightly modified version. Even such small political intervention of Community authorities into CEPT's and the national administrations' responsibility could not have been envisaged earlier.

In March 1983, shortly after the *Groupe Spécial Mobile* was set up, the

Council adopted a directive concerning the co-ordination of national activities in standardisation. Half a year later the Commission presented a set of ”lines-of-action” aimed at creating a single European telecommunication market. Among other measures they suggested the formation of an expert group which was to be responsible for formulating middle- and long-term development-aims on Community level and for defining and implementing joint R&D programmes in this field. To foster a single market for user equipment, preconditions for a Europe-wide harmonisation of technical standards were to be determined. Furthermore, the generation of a unified infrastructure, namely an Integrated Services Digital Network (ISDN) and mobile telephony, was proposed, the latter referring to the GSM-project. All these measures can be seen as attempts to open up telecommunication as a legitimate field for policy on Community level, and to establish the Commission as an important actor in this field. For the time being this was just a political programme – under the circumstances it was too ambitious to show immediate results.

So by the time the organisational foundations for creating a joint European mobile telephone standard had been laid down within CEPT, an intensive discussion about the definition of a Community telecom-policy had just begun. From the start it was foreseeable that technological strategies would be an important dimension of such a policy. But the GSM project was set up and, at first, also taken over independently by CEPT without any agreement with the Commission (Commission, 1990: 39).

Setting the Scene

Some basic features of the standard to be developed had already been decided upon by delegates of the participating administrations before the work of the *Groupe Spécial Mobile* began:

- The new system was to allow the co-existence of more than one system on the same territory in order to allow competition between several operators in one national market.
- To improve the chances of commercial exploitation, the standard was not to include any components or technical solutions which were protected by intellectual property rights. It was to be made available to every interested producer.
- Furthermore, it was not to define properties of devices but functional specifications which would allow the development of competing but compatible technical solutions.

This last point is of some importance because it highlights that the GSM-Standard was planned as, and finally became, an anticipatory, ex-ante standard. It was ”developed during the R&D phase, thus largely pre-empting competition between alternative technologies” (OECD, 1992: 235). In contrast to detailed technical specifications for devices, an anticipatory standard does not lay down a certain technical realisation, but it describes a set of functions which components must comply with. In a strict sense such a standard does not define a specific technique, but it structures future technological development. It initiates a development which might, with hindsight, be interpreted as a ”technological trajectory” (Dosi, 1982). The producers and not the standard-setting body are responsible for realising the system-specifications. One could say in a simplified way that the GSM-Standard ”only” describes obligatory functional interfaces between major building blocks, laid down in a so-called reference configuration (see below Fig. 3). And the producers’ further research and development must be oriented towards this configuration. These standards are, as Werle argues, elements of technological knowledge, not of products, and they ”serve as a medium to coordinate this development” (Werle, 1998: 8).

In an early phase of the project the question of which technology was to be developed and which services were to be offered by the new system was disputed:

> From day one the work was directed towards a second-generation cellular system, since many countries already had first-generation systems … in use or in implementation stage. [But] here was no decision or directive that the new system should be digital, since there was uncertainty as to what transmission mode would best meet the requirements. However, there was agreement that the new system must take into account recent developments in the telecommunication field (Haug, 1992: 7).

Not before 1984 did the participating administrations agree that GSM should be basically a telephone system, that is, optimised for speech-transmission but still allowing as much access as possible to the services the, then planned, Euro-ISDN would offer. And because ISDN is a ”digital” system, this meant that digital speech-transmission on the radio path had to be developed to reach a marketable standard. At that time nobody knew exactly how this was to be achieved. It was evident though that it would require quite basic scientific and technological research particularly to solve the radio propagation problems.

Immediately after this first description of tasks had been compiled – GSM will be a telephone system with ISDN options – the circle of participating actors was broadened. R&D jobs were subcontracted to industries and research institutes, but they were for the time being not allowed access to the discussions and decision-making in the GSM Group. As long as the project was carried out under the auspices of CEPT, only members of administrations or network operators could participate directly in the decision-making process in the *Groupe Spécial Mobile*. The results of the know-how-suppliers’ work were presented to the CEPT committee fiduciary by the respective national delegations. This did not change until summer 1987 when representatives of industry were admitted to the GSM meetings for the first time.

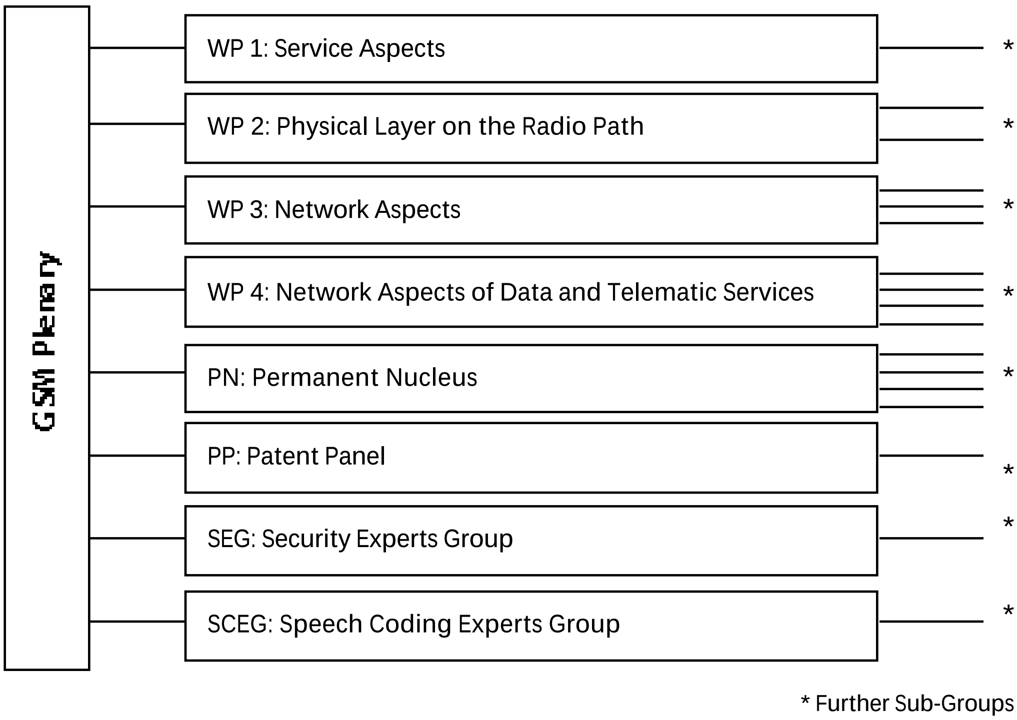
In the first half of 1992 the work of the *Groupe Spécial Mobile* was almost done. During the project the European (mobile-)telecommunication scene changed dramatically. New producers appeared, new operators and service providers strove to enter the markets and were admitted. New forms of collaboration between these groups and the telecom-administrations were institutionalised. Quite a few of these structural changes were generated in the course of and by means of the GSM project.

The Formation of a GSM Network[3]

Today it is undeniable that the development of the GSM standard has been commercially the most successful European technology-project so far. Furthermore, along the way a Europe-wide network of firms, research institutes, technical problem-definitions, and administrative bodies has been built which is unequalled. A characteristic feature of this network is its lack of one central steering body. There is no single GSM system-builder. On taking a closer look even the most likely candidate for such a position, the *Groupe Spécial Mobile*, turns out to be a constellation of a variety of actors, different in kind and origin. This group was not a stable "social framework" for technological activities, but rather "an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of" (Callon, 1987: 93 with respect to his actor-networks). This double-structure can be shown in a sketch of the GSM network's development from its outset until the middle of 1988.

In early 1984 the plenary of all the eighteen national delegations in the GSM Group determined three major tasks to be dealt with: the specification of *services*, the *radio-interface* and *network aspects*. During the following year work increased steadily and eventually the plenary decided that the tasks should be treated in separate groups called Working Parties (WP). This was the first time in the history of CEPT that an organisational structure below plenary-level (see Fig. 1) was implemented for

Fig. 1: CEPT Groupe Spécial Mobile (May 1988)



treating technical problems. From then on the detailed technological work was done in these Working Parties (in the beginning only WP1, WP2 and WP3) and the plenary turned into a co-ordinating committee, defining tasks for the subdivisions, and discussing and acting upon the results of their activities.

At the beginning of 1986 the GSM Group opened an office in Paris called Permanent Nucleus (PN). Its task was to co-ordinate the specification process and it also functioned as an editor of the interim results and the standard as a whole. When this office was set up by CEPT the EC Commission made an attempt to increase their chances of influencing the GSM process through institutional participation. The Commission offered to finance the secretariat and wanted it to be located in Brussels. This looked like a Trojan Horse to the CEPT administrations, and they turned the offer down. The story is revealing in two respects. On the one hand it shows that the Commission's efforts to become a trans-national actor in telecommunication policy was interpreted by the – in that era still dominant – national actors as a threat to their sovereignty (and rightly so). On the other hand it is obvious that the Commission regarded the development of new "European" telecom-technology as a crucial lever to help it strengthen its position in this field.

A further subdivision of the *Groupe Spécial Mobile* took place in October 1987 when the responsibility for telematic services was shifted from Working Party 3 to the newly founded Working Party 4. Finally in May 1988, the Working Party Patent Panel (PP) was set up to investigate whether planned specifications violated existing patents. Further sections were concerned with speech coding technology (SCEG) to transform analog speech into digital signals and with data-security in the GSM system (SEG).

But the GSM Group and its subdivisions were only one part of the whole standardisation project, and compared to the overall number of participants, a relatively small one at that. In addition there were further expert groups, some of them organised by the respective national Telecommunications Administrations. The following passage describes the German situation as an example of this principle.

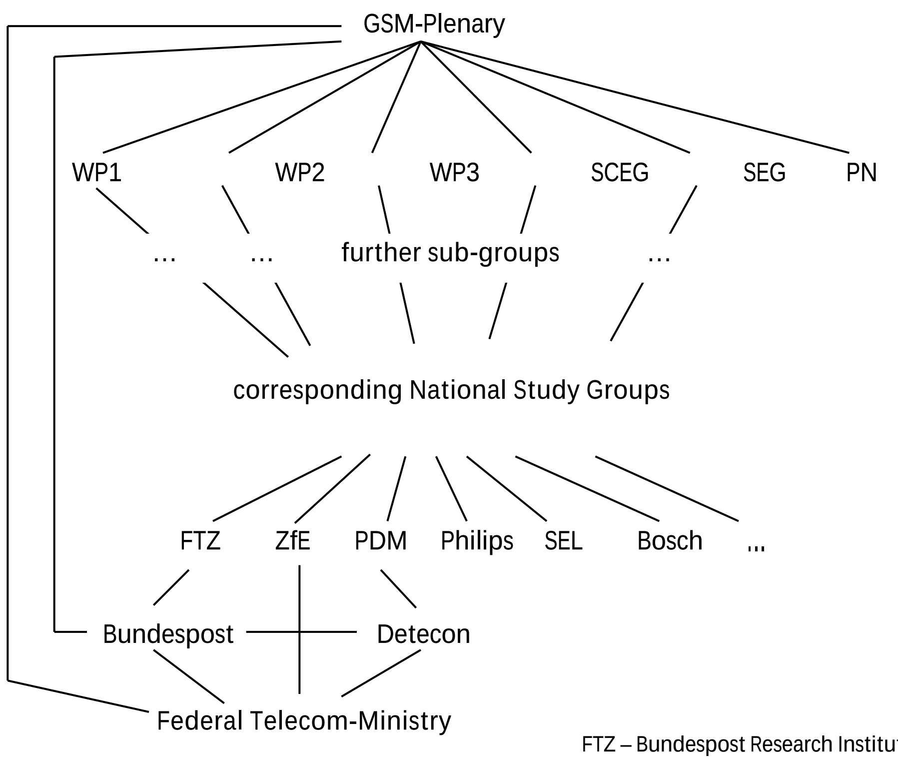
Networking beyond CEPT

From the middle of 1987 onward (after the Group had agreed upon the basic parameters of the standard, see below) the national administrations' expenditure of work for the standardisation activities within in the *Groupe Spécial Mobile* increased drastically. Parallel to that they had to prepare the set up of their own GSM systems which was also a quite demanding and time-consuming effort. All this could not be handled by the personnel available and therefore the German federal Telecommunications Ministry and the public operator *Deutsche Bundespost* decided to entrust all of their GSM-related assignments to Detecon, a subsidiary of the latter. Detecon put together a team called *Projektgruppe Digitale Mobilkommunikation*, PDM (Project Group Digital Mobile Communication). In the beginning its team consisted of 39 experts dispatched from the Ministry and the *Bundespost*. Until 1992 their number increased to more than 600.

Also in 1987 the – already quite complex – structure within CEPT and its membership was augmented by further National Study Groups set up by the respective administrations, in Germany by the *Projektgruppe* PDM. Here experts from the administrations collaborated with industrial and academic technicians and researchers to develop and test specifications. The tasks of those teams corresponded to the division of labour within the GSM Group. In the following years some one thousand technicians, scientists and engineers contributed in one way or another to the GSM standardisation project.

The organisational differentiation, that is the set up of subdivisions within the CEPT-Committee and the determination and step-by-step widening of the circle of participants, was synchronous with the differentiation of tasks. In other words: the organisational and institutional forms in which the technical specification-work took place were created parallel to the progress made in this work. The process was guided by the definition of problems to be faced, which became clearer in the course of time. It is for this reason that the GSM network in 1986 was different from the one in 1988. And because of this it would

Fig. 2: GSM Working Levels (German Perspective)



FTZ – Bundespost Research Institute
ZfE – Ministry Development Office
PDM – Study Group Digital Mobile Com.

be misleading to see it as a social framework which was built for development-work to come. The terms ”social context” and ”technical content” with regard to the GSM development refer to one another, not only in the sense that one could not exist without the other. They have been developed and raised uno actu – as a network of heterogeneous elements. In retrospect one can describe the GSM network as an association of organisations. But in the making, certain technological problems and possible solutions, concepts and artefacts, have been constitutive elements for the configurations which were generated and re-generated time and time again in the progress of the work. Networking heterogeneous elements was exactly the way in which the development of the GSM standard was executed.

The simultaneous creation of interconnections between actors and of a technology was not limited to the sphere of technology-development in the stricter sense. In order to prove my point it is necessary to go into the GSM standard in some detail.

Development of Technology as Politics by Other Means[4]

As the GSM standard applies to a technology that did not exist when the work started (digital speech transmission on the radio path), the practical feasibility of intended specifications had to be tested before they could be fixed. Therefore the participating national Telecommunications Administrations put out to tender so-called Validation Systems in the late summer of 1986. The envisaged test programme concentrated on different modes of speech coding (i.e. digitalisation) and speech transmission. To answer this call the major European suppliers of telecom-technology formed trans-national consortia, and the *Groupe Spécial Mobile* selected eight of the models they had been tendered for detailed investigation. These were not fully equipped radio communication systems but rather provisional combinations of components for particular experiments. Based on the evaluation of tests carried out in metropolitan Paris, the GSM partners decided upon the system's basic parameters in the first half of 1987.

The agreement was preceded by a fierce dispute essentially concerning the bandwidth to be used by the GSM system. The French supplier Alcatel – backed by *France Télécom* and the German Telecommunications Ministry – strongly supported an already rather elaborate digital concept, then the only one of its kind. The concept had been developed by German SEL, then a subsidiary of the US multi-national ITT, in collaboration with AEG in the early 1980s (for more details see Bender, 1996: 113-18). It was called CD900 and it used a fairly broad radio channel of 6 MHz which facilitated a simultaneous transmission of sixty speech channels per transceiver with each speech channel using 100 kHz. This was quite unusual, as the existing analog systems used only 20 or 25 kHz. An SEL-lead consortium submitted a Validation System based on this concept in September 1986. All the other suppliers handed in models using a narrower bandwidth. Only a few weeks later, in December 1986, the newly founded Alcatel NV took over IIT's telecommunication business and, with that, also SEL. Now the new owner of CD900, Alcatel lobbied strongly to persuade the GSM partners to accept this concept as the basis of a future European cellular radio communication standard.

Alcatel was unable to score an immediate success. Following the field-trials of the Validation Systems in and around the French capital, the GSM's Working Party 2 (responsible for the radio interface) and Speech Coding Experts Group (SCEG) agreed unanimously that a narrow band solution was preferable to the CD900 model. The main reason given for their decision was that the capacity of the broader band would be higher than needed and that this would, in the end, make the infrastructure unnecessarily expensive.[5] Furthermore there was fear that the rigorous schedule (see below) for implementing the service could not be maintained in the other case, as it was foreseeable that a decision opting for the unfamiliar broad band technology would call for even more R&D activities than was needed anyway.

The judgment was challenged by Alcatel which claimed it was not objective. The following dispute cannot be presented in detail here. Its outcome was as follows (for details see Bender, 1996: 122-28): The decision against the CD900 model was maintained in principle, but the basic parameters of the standard were explicitly defined as a compromise, that is to say, as a combination of technical concepts and models which had been developed by the various consortia to meet the call for Validation Systems. Due to this compromise the GSM standard became highly complex. The description of its specifications covers about 5,000 printed pages. But only this compromise allowed all the key players in the European telecom-industry to be part of the GSM project.

The definition of the standard's basic parameters as a compromise not only determined a direction for further development work. It was also, as all the participants knew, a decision based on industrial policy. Had the *Groupe Spécial Mobile* opted for one concept as an integrated whole instead of a "patchwork" of different solutions, it would for one thing have encouraged a specific technology. But more importantly it would – willy-nilly – also have appointed the consortium that sent it to the Paris field-trials as main contractor. Under the circumstances this would have been Alcatel, because their CD900 was the most elaborate conception those days. Such dominance of one company was something the CEPT as well as the EC Commission were absolutely determined to avert. For quick results of the project and for the European system's economic success it was crucial that the standard be supported by as many administrations and companies in the sector as possible. This could not be achieved by administrative measures. Which government would have been able to induce, for instance, Ericsson or Siemens to accept the role of a sub-contractor under their competitor Alcatel? But it could be realised by transforming the politically desired compromise into a set of technological specifications. Using the terminology of the actor-network theory: It was realised through networking the most important actors in the European telecom-industry as suppliers of concepts and components with a certain mode of speech transmission (with a bandwidth of 200 kHz divided in eight speech channels, each 25 kHz), system-operators, a specific coding technology and other entities. The result of these networking activities was a configuration of heterogeneous elements whose stability grew gradually as the number of elements increased.

Furthermore, the definition of the basic parameters of the standard did, at the same time, set the scene for a competitive European market for mobile communications in the future. This too was done by means of a step-by-step stabilisation and expansion of the network and by including more elements.

System Structures and Market Structures

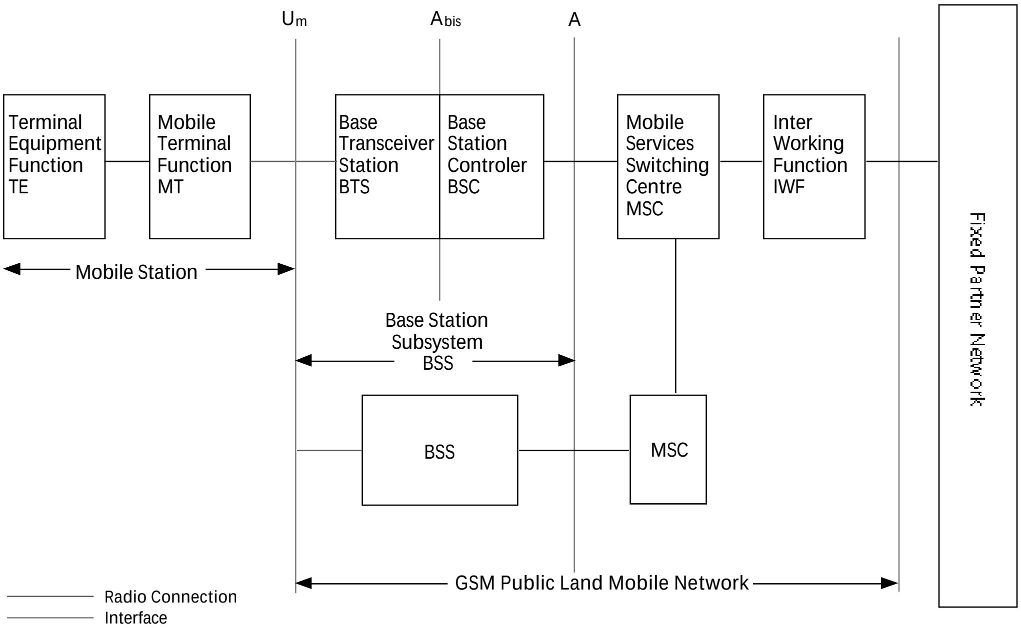
In the summer of 1987 the Council asked the Community members to clear a section of the 900 MHz frequency band for the GSM System. This band has been reserved for private mobile communication in Europe since 1978. The measure enabled this frequency band to be stabilised as an element of the GSM network. Simultaneously a Council decision was issued, recommending the joint introduction of the system in Europe. In September 1987 four of the future GSM operators signed a Memorandum of Understanding which fixed so-called milestones in a tight schedule for introducing GSM services starting in 1991 (see Bliksrud, 1990; Bender, 1996: 133-42). Nine other operators and regulatory bodies joined the commitment immediately. The signatories set up a study group (GSM MoU-Group) to solve administrative and technical problems that might be obstacles to this ambitious undertaking in close collaboration with the *Groupe Spécial Mobile* and the Commission.[6]

As a consequence of these decisions (EC-)Europe turned into a ”GSM region”. Since then there is no way to avoid the GSM technology for everybody with an interest in mobile communications, may s/he be user, operator, supplier or regulator. The GSM project became a ”obligatory point of passage” (Callon, 1986: 27; Law & Callon, 1992: 47), and the single European market for radio communication services and components became, for the foreseeable future, a GSM market. And not only in the very general sense that GSM technology is traded in this market, as a closer look at the standard shows.

It structures the system into interacting functional subsystems. The subsystems are not machines, as has already been mentioned. The GSM specifications ”specify in fact mainly the behaviour of the system as seen on interfaces between machines and not the internal working of these machines” (Mouly & Pautet, 1992: 84). The specification of the Base Station Subsystem (BSS, see Fig. 3), for instance, does not describe how this Subsystem must be constructed but determines its function, what it has to do. How this function is realised in detail may differ from supplier to supplier. But they all have to tailor their devices and software in such a way that they meet the interface-specifications and minimal demands defined in the standard. One consequence of this kind of standardisation is that system operators can combine equipment from different producers, which enhances their freedom to select suppliers.

But more importantly than this economic benefit is for the argument supported here that the interfaces between the functional subsystems do not only separate building blocks of the system but also markets. They structure the GSM market in segments for user equip-

Fig. 3: GSM Reference Configuration



ment (mobile phones, fax-machines etc.) and infrastructure equipment, whereby the latter is split into segments for equipment that fulfils the switching-function (MSC), the transmission-function (BSS) etc. And because the specifications are available to every producer who is interested, this weakens the market power of the few suppliers of switches. The latter used to be in a rather comfortable situation because the interfaces of their systems were proprietary and the producers of radio technology had to co-operate and, likely, pay licence fees to ensure the smooth interaction between the transceiver and switching technology.

The structuring of the single European market for cellular radio components took place by means of, that is to say: *as* the technological specification of the GSM standard. The technological procedures carried out during the GSM project are fundamental to this market in the sense that the generation of market-structures has in part been carried out as a specification of this particular technology. This does, to be sure, not include the demand. Nobody expected the economic success of the service to be so enormous and for it to arrive so soon. But fundamental technical and institutional conditions of the commercial exploitation and operation of the new technology in Europe, and later on nearly world-wide,[7] were generated in the same process and (in part) by the same procedures as the technology itself.

This also applies to conditions for new forms of regulation. A new mode of regulation has now become possible. It is characterised by a shift in competence from national bodies to newly founded European ones and by a restructuring of the procedures of standardisation and type approval for telecommunication equipment which were customary until the early 1990s. One major step in this direction was the GSM project, another was the foundation of the European Telecommunications Standards Institute (ETSI) in 1988. This institute took on the role CEPT used to play in European telecom-standardisation. One of the principal changes brought about has been a greater participation of producers in standardisation (see Besen, 1990) as has been the case in the GSM project since June 1987. The GSM related activities were transferred to ETSI in March 1989.[8]

The establishment of ETSI was one of the key suggestions in the Commission's Green Paper on Telecommunications, published in June 1987. The publication is usually seen as a milestone in terms of both the economic integration of Europe and the structural changes in the telecommunication sector in the 1980s, and rightly so. But the strategic options formulated in this document can already draw on socio-economic changes that were generated in the course of the GSM project. The Commission's document from 1983 introducing "lines-of-action" towards a pan-European telecommunications sector was not much more than the political programme of a relatively weak actor. Four years later the tables had turned. Now the Commission could demand and obtain regulatory competence. What had happened? In between, conditions were systematically created that undermined national forms of regulation and made a re-regulation on a European level look not only possible but even necessary. And it was, in part, the technological procedures taken out within the GSM project that functioned as carriers of this socio-economic change. This is why this project should be taken as a constitutive element of both the developments: the changes in the telecommunication sector and the economic integration of Europe.

Conclusion

In the first part of this paper I argued that for an understanding of the development of technologies and innovation, a focus on networking rather than on networks proves the more fruitful analytic perspective, and that a sociological analysis should not ascribe formative capacity exclusively to the social elements of the network under investigation, i.e., to people, rules and organisations. The second section tried to show that what one might in hindsight identify as a stable institutional framework of the GSM project has been continually transformed throughout its course and that this institutional differentiation corresponded to a large degree with the specification of technological problems that evolved during work in progress. Although it is true that the institutional setting influenced the direction the technological development took, the same also holds vice versa. Therefore it is rather doubtful whether one can use the "institutional framework" – or network of actors if the term is used correspondingly – as an *independent* variable[9] in an explanation of the project and its outcomes. It did not occur independently of or in preparation for the technological work itself. This work, the specification of and the dealing with problems, was carried out by configuring heterogeneous elements, ”technical” ones as well as actors, rules and interests in a process described above as the formation of a GSM network. So this network was not simply a stable, structural prerequisite of the standardisation work to come but was one of its results as well. It was in the very project that the participants generated both the standard (its ”content”) and a variety of contexts that did not exist before and for which technological problems, conceptions and artefacts (or software) had been formative elements.

The third section of this paper attempted to show that this does not merely apply to the sphere of technology-development in the stricter sense. New markets have been created, new rules and institutions have been implemented which both foster and express the stronger position of genuinely European organisations in telecom-regulation, as well as the higher degree of integration of Europe’s national economies and – therefore – nation-states. The project has changed economic and social conditions on this continent to an extent that is significant not only for those who took part in the project or have a vested interest in mobile communications, but for all Europeans, even for the few of us who have never touched a GSM phone and probably never will. Taking this into account, the R&D project, like similar other ones, turns out to be an instructive field not only for science and technology studies. One may use the title of a reader published by Bijker and Law (1992) in a slightly revised version to describe the societal relevance of this kind of projects: they can serve as empirical examples of transforming – building, if you will – society by shaping technology.

The GSM project is certainly a particular case which cannot be generalised without any problems – and if it was only for the structural changes it brought about. The question of how effective this mode of transforming social reality in the course of an R&D project is and how fraught with societal consequences can only be answered by empirical research. But it is, I think, important enough to be taken seriously in analysis and for a theory of contemporary capitalist societies. An understanding of the role of large R&D projects in society and of those who are in a position to influence it has become important, not just for its own sake but as part of our general understanding of society itself.

Notes

1 There is another important conclusion: If this holds true e.g. university-industry interaction in innovation is not just a matter of unidirectional handing over ready-made knowledge comparable with a relay race. To grasp the processes of definition and re-definition of problems to be solved the concept of ”technology interchange” as suggested by Gibbons *et al.* (1994: 86-89) is more suitable. One just misses an important point when one thinks of this simply as transfer of products from one distinct context into another one. This is not merely of academic interest but of vast political import. Public support for basic research should under these circumstances not be taken as *a science- or techn*ology-push approach but should be considered, to quote Martin and Johnston (quoting themselves Callon 1994), ”as an investment in network

reconfiguration and renewal. Public funding for science generates new combinations of organisational and individual relations, encouraging new mechanisms for interaction and collaboration, out of which may then be created new scientific and technological options." (Martin & Johnston, 1999: 50)

2 The collection of data for the reported case study started near the end of 1989 when the introduced standardisation project was in full swing. The material to draw upon has therefore been mainly unpublished literature (lectures, company material etc.) and reports about conferences in special journals. Based on the analysis of this literature experts for interviews were selected. All of them were technicians in responsible positions either in the telecommunication-industry, in relevant industry associations or in the telecommunications administration in Germany (most of them) or in Switzerland. And all of them participated in the strategic decision-making processes in the Groupe Spécial Mobile. The interviews were conducted between October 1992 and May 1993. More results of this study are published in Bender 1996 and 1999. In this article the GSM case is discussed as an example for network formation and transformation of social structures by shaping technology. For literature which focuses on issues of international standardisation of telecommunications see e.g. Schmidt & Werle, 1998.

3 The term "GSM network" denotes the whole of all elements which were configured in the course of the project whereas the expression "GSM system" refers to the technical infrastructure.

4 I owe this phrase to Latour's well known statement: "Science and technology are politics pursued by other means, ... the only way to pursue democracy is to get inside science and technology, that is, to penetrate where society and science are simultaneously defined through the same stratagems." (Latour, 1988: 38-39)

5 With the solution eventually chosen for the standard each Base Transceiver Station (BTS, see Fig. 3) can transmit eight or sixteen speech channels simultaneously, depending on the Codec used (a Codec transforms analog signals into digital ones and vice versa). Multiplex procedures and other measures to improve the use of frequency left aside, this means that in the territory covered by a BTS eight or sixteen calls can be handled at the same time (the CD900 model offered sixty). In less densely populated regions this is, in principle, good value because, as a rule of thumb, the narrower the band it uses, the cheaper the BTS. But then you need to set up more BTS in areas with very high traffic, e.g. city centres or airports, to serve the same number of users as a BTS utilizing a broader frequency band. Therefore in those areas the costs for a narrow-band infrastructure may be higher than the expenses incurring for the alternative technology (for those and more technical questions of mobile communication see Mouly & Pautet, 1992 and – less expertly – Bender, 1996: 97-106).

6 Time was a critical factor throughout the project. It was foreseeable that the cellular systems in some European countries would reach the limits of their capacity in the late 1980ies. Severe delays in the GSM project could have caused their operators to built up new analog – and "national" – systems. This would have limited the perspectives of a pan-European cellular system seriously. This explains why the Commission pressed so hard to speed up the standardisation process.

7 Today GSM systems are used in more than sixty countries, most of them in Europe, Asia, Australia and Arabia.

8 This was when the abbreviation GSM was given a new meaning. Now it stands for Global System for Mobile Communications and is a trademark.

9 This is what Werle seems to suggest in his General Model for analysing standard-setting. He uses the term to describe "a system of formal and informal rules concerning among others membership, working procedures and decision-making" (Werle, 1998: 9). The reference to rules of mem-

bership indicates that he thinks of organisations that are structured by this system of rules. What I would like to point out is that in the GSM case some of the important organisations (the National Study Groups, the Projektgruppe PDM, the MoU Group) and the rules, particularly those concerning their working procedures would never have existed without the project, that is independent of its content.

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