Overview and Definition of Software Download for RF Reconfiguration

DL-DFN

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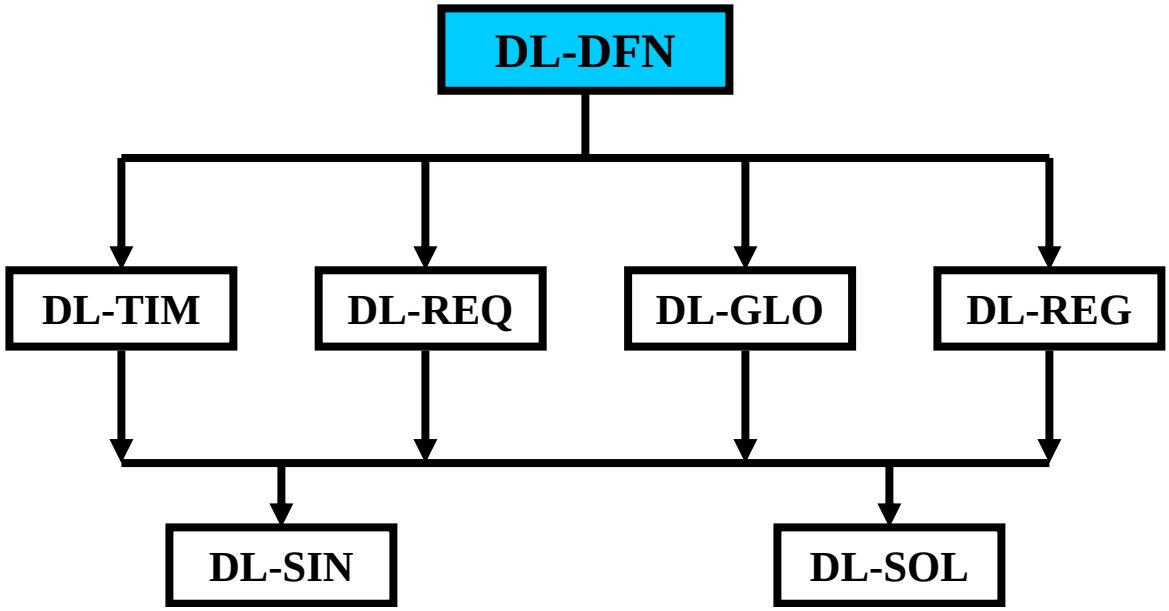
Preface

This document provides a complete high-level perspective on the scope of radio software download (that is, the downloading of software for RF reconfiguration) in the context of software defined radio (SDR) terminals and base stations with reference to applications, requirements, methods and implementations. The document presents a list of considerations that are relevant to the development of detailed requirements. The SDR Forum Download Working Group developed this document with input from the Terminal and Network Architecture Working Group.

This document is the first in a series of SDR Forum documents on radio software download[1]. The other documents in this series are:

- DL-TIM: Timelines for Software Download for RF Reconfiguration
- DL-REQ: Requirements for Software Download for RF Reconfiguration
- DL-GLO: Report on Global Radio Technology Development Organization Perspectives on Software Download for RF Reconfiguration
- DL-REG: Report on Global Regulatory Views on SDR and Software Download for RF Reconfiguration
- DL-SIN: Software Download for RF Reconfiguration Security and Integrity
- DL-SOL: Specifications of Common Solutions for Software Download for RF Reconfiguration

The relationship of these documents is seen in the figure below. DL-DFN is the overarching document that provides a foundation for the remaining documents and drives their development. Documents DL-TIM, Dl-REQ, DL-GLO, and DL-REG are parallel documents that provide the basis for further work in DL-SIN and DL-SOL. It is these latter two documents that are the ultimate goals of this series of SDR Forum documents on software download. As work on these documents progresses, certain documents such as DL-SIN and DL-SOL may be combined into a single document.



Relationship of SDR Forum Software Download Documents

[1] This series of documents utilizes the work of earlier SDR Forum publications including the SDR Forum Technical Report 2.1, “Architecture and Elements of Software Defined Radio Systems as Related to Standards,” November 1999.

Overview and Definition of Software Download for RF Reconfiguration

1. Introduction

This document provides a complete high-level perspective on the scope of radio software download (i.e., the downloading of software for RF reconfiguration) in the context of software defined radio (SDR)[2] terminals and base stations with reference to applications, requirements, methods and implementations. The document presents a list of considerations that are relevant to the development of detailed requirements. In particular, the document concentrates on the download of software that has the potential to alter the radio parameters which are considered to be important to the radio regulatory community, network operators, service providers and manufacturers. In the context of this report, the term "software" means both executable code (i.e., program code) and data used by this code. Commercial wireless is the initial focus area of current deliverables within this topic area. Although the focus is on commercial wireless in this document, other sectors such as defense communications and civil government are closely related.

The report utilizes information developed by the SDR Forum that has been published in earlier SDR Forum Documents such as SDR Forum Technical Report 2.1, "Architecture and Elements of Software Defined Radio Systems as Related to Standards," [Reference 2].

The report provides the definitions of SDR and software download within the context of the series of documents on radio software download being developed by the SDR Forum. The scope of this radio software download work and the beneficiaries of radio software download are then described (Sections 2 and 3, respectively). There are numerous ways to categorize the download of software: Section 4 describes how the SDR Forum categorizes software download in this series of documents. Section 5 provides radio software download scenarios that are the primary drivers of the radio software download work in the SDR Forum. This is followed in Section 6 by high-level technical and regulatory considerations for radio software download. Radio software download methods and implementations are overviewed in Section 7. Finally, in Section 8, the document concludes with a proposed way forward for interacting with:

- Recognized Standards Development Organizations (SDOs) in developing recognized standards and specifications, and
- Regulatory bodies involved in the development of rules and regulations applicable to SDR-capable devices.

[2] Concepts presented herein may be applicable outside the context of SDR.

1.1 Definition of Software Defined Radio

For the purpose of this series of SDR Forum documents on radio software download, the following definition of software defined radios is used:

> *Software Defined Radio.* Software defined radios are elements of a wireless network whose operational modes and parameters can be changed or augmented, post-manufacturing, via software.

To amplify on the above definition, software defined radios use adaptable software and flexible hardware platforms to address the problems that arise from constant evolution and technical innovation in the wireless industry, particularly as waveforms, modulation techniques, protocols, services, and standards change. This definition can also address the implementation of radios that facilitate satisfying the increasing need for users to communicate as they move between different wireless network environments.

A software defined radio in the SDR context goes beyond the bounds of traditional radio and extends from the radio terminal of the user, through and beyond the network infrastructures and supporting sub-systems and systems, to access not only other users but also suppliers of value-added applications. SDR as a concept spans numerous radio network technologies and services, including cellular, personal communications services (PCS), third generation wireless (3G) and beyond, mobile data, emergency services, messaging, paging, and military as well as government communications.

The above definition of SDR and ensuing discussion provide a broad perspective on the technology. The term "software defined radio" has been used to describe a broad range of devices whose common denominator was the ability to change, to some degree, their operating parameters and behavior via software. Whether or not a device meets a particular definition of SDR often depends on the degree and/or means by which the device's parameters change.

At one extreme, some interpretations of SDR require not only a very broad range of flexibility, but that the device itself have enough resident intelligence to seek and monitor the existing spectrum situation, and to reconfigure itself to take maximum advantage of it. These radios are sometimes called adaptive intelligent software defined radios or "cognitive radios."

By contrast, a regulatory definition of SDR that is more focused is:

> *Software Defined Radio.* A radio that includes a transmitter in which the operating parameters of frequency range, modulation type or maximum output power (either radiated or conducted) can be altered by making a change in software without making any changes to hardware components that affect the radio frequency emissions.

The United States Federal Communications Commission (US FCC) adopted the above regulatory definition in its Software Defined Radio First Report and Order[3]. The rules that the

[3] FCC Report and Order FCC-01-264A1, "Authorization and Use of Software Defined Radios", ET Docket No. 00-47, September 14, 2001.

FCC adopted allow any party to install or make changes to application or other software in a radio that does not affect the authorized operating parameters The above regulatory definition is more specific than the broad definition provided at the start of this section, however it is compatible in the sense that it can be considered a subset of the broader definition. The definition promulgated in the FCC Report and Order is a reasonable regulatory view that has broad global applicability and may be considered by other regulatory agencies around the world as a basis for common understanding.

1.2 Definition of Radio Software Download

For the purpose of this series of documents, the SDR Forum provides the following definition:

> *Radio software download:* The process of delivering reconfiguration data and/or new executable code to a SDR device to modify its operation or performance.

Thus, the term "radio software download" as used here is not to be confused with the downloading of any software over the air. In addition, the above definition makes a distinction between radio software download and non-radio software download (e.g., a wide variety of subscription or free news and information, proprietary corporate data, email and multimedia material such as MP3 files[4]).

Examples of reconfiguration data are new parameters for modulation techniques already existing in the radio, new power levels, new operational frequencies or other operational parameters that are used by program code already installed in the SDR device.

Examples of executable code considered to be radio software are programs to be installed in SDR-enabled terminals or base stations that enable new digital signal processing algorithms, "bug" fixes and operational updates or a new radio air interface.

Regulators should be concerned with reconfiguration data and executable code that affect the RF operating characteristics of the device rather than user applications. Service providers, network operators, and manufacturers are interested in all aspects of both radio software download and non-radio software download.

It is important to note that there are standards organizations and private organizations which are interested in both radio software download and non-radio software download, and are developing specifications and standards for end-to-end download protocols that may support one and/or the other.

These end-to-end download protocols include capabilities such as authentication, delivery verification, transaction logging, billing, etc. These same capabilities are of interest to those organizations focused on radio software download of reconfiguration data and executable code that affects key RF parameters within the radios. These protocols and capabilities should also be

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[4] There are authentication and authorization mechanisms that have already been developed for non-radio or content information software download that may have applicability to radio software download as well.

of interest to regulatory agencies. The SDR Forum is in the process of preparing a report to the United States FCC that will include a summary of the activities of these organizations as might be applicable to radio software download. The report will put particular emphasis on the security aspects of radio software download[5]. Therefore, the SDR Forum has interest in both areas; for radio software download it is a principal area to be influenced and developed, and for non-radio software download it is an area from which knowledge, specifications and developments might be leveraged in the radio software download area as appropriate.

1.3 Additional Definitions Relevant to Radio Software Download

Radio Hardware: The basic hardware within a wireless device that performs the radio interface functions and includes the radio RF as well as baseband signal processing.

Radio Software: The primary software within a wireless device that is coupled with the radio hardware to derive the overall "radio" functionality. Ancillary software (such as control) that may be needed as a consequence of the primary software is an inherent part of this definition.

Radio software is not to be confused with user applications and content (such as download of credit card billing information, stock market status, MP3 software, etc.).

The categorization of software download is expanded upon in a later section of this report.

[5] SDR Forum Document, Report on Issues and Activity in the Area of Security for Software Download (Report to the United States Federal Communications Commission, Summer, 2002.)

2. Scope of Radio Software Download for Software Defined Radio

A SDR device potentially offers ultimate reconfigurability, via radio software download, of part or all of its radio functions. The term "SDR device" is the terminology used herein to mean both terminals and base stations for commercial wireless, military and civil government applications. However, the overall scope of software download extends beyond the terminals and base stations. SDR impacts many layers of a commercial wireless network, as illustrated in Figure 1. Benefits from SDR will be realized from the physical layer to the user applications plane.

Regulators should be concerned with reconfiguration data and executable code that affect the RF operating characteristics of the device rather than user applications. Service providers, network operators, and manufacturers are interested in all aspects of both radio software download and non-radio software download. [Reference 1]

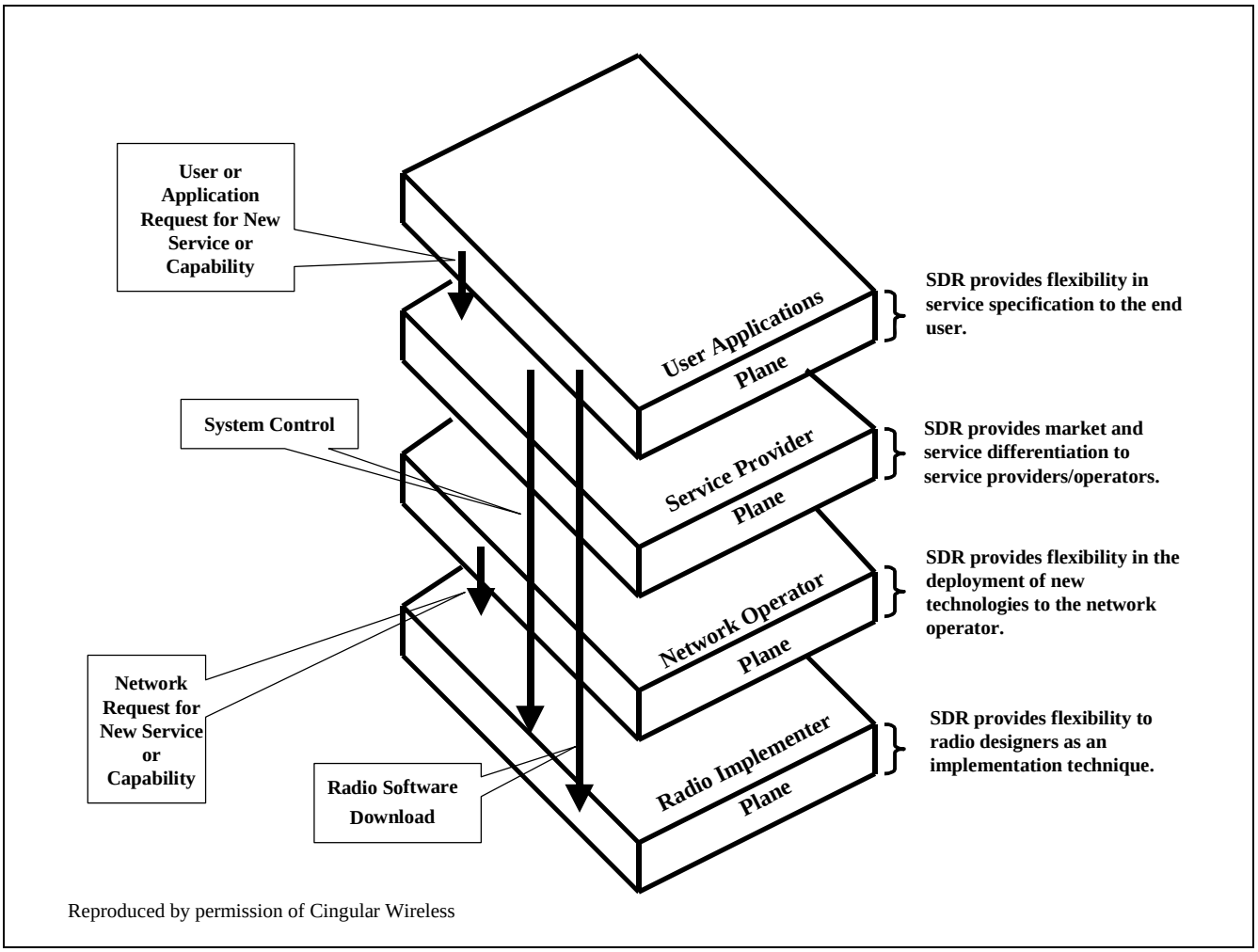

Figure 1. Multi-Dimensional Aspects of Software Defined Radio

3. Beneficiaries of Radio Software Download

Many parties potentially benefit from the prospect of radio software download. Moreover, different parties will have different requirements for radio software download. Some examples of potential beneficiaries are:

- Manufacturers
- Network Operators
- Service Providers
- Third party software developers
- Subscribers and users
- Military communications users
- Civil government communications users (e.g., public safety agencies)
- Regulators

Manufacturers benefit from the ability to use a common design for multi-functional radios, thereby obtaining a cost benefit from a size-of-market point of view. The commercial wireless, military and civil sectors benefit from this cost reduction due to market size. They also benefit from enhanced interoperability, ease of system upgrades, and ease of "bug" fixes. Subscribers and users benefit from enhanced functionality of their SDR-capable devices. A new market is created by SDR for third party software developers. Finally, regulators benefit from the potential for spectrum efficiency afforded by SDR devices.

4. Radio Software Download Categorization

There are a number of ways to categorize the software that can be downloaded into an SDR-capable device. The distinctions that are important for the context of this series of SDR Forum documents on software download are[6]:

- Radio software vs. non-radio software
- Primary radio software vs. supplemental or ancillary software
- Executable code vs. data

Figure 2 provides the SDR Forum view of how the download of software can be characterized using these categories.

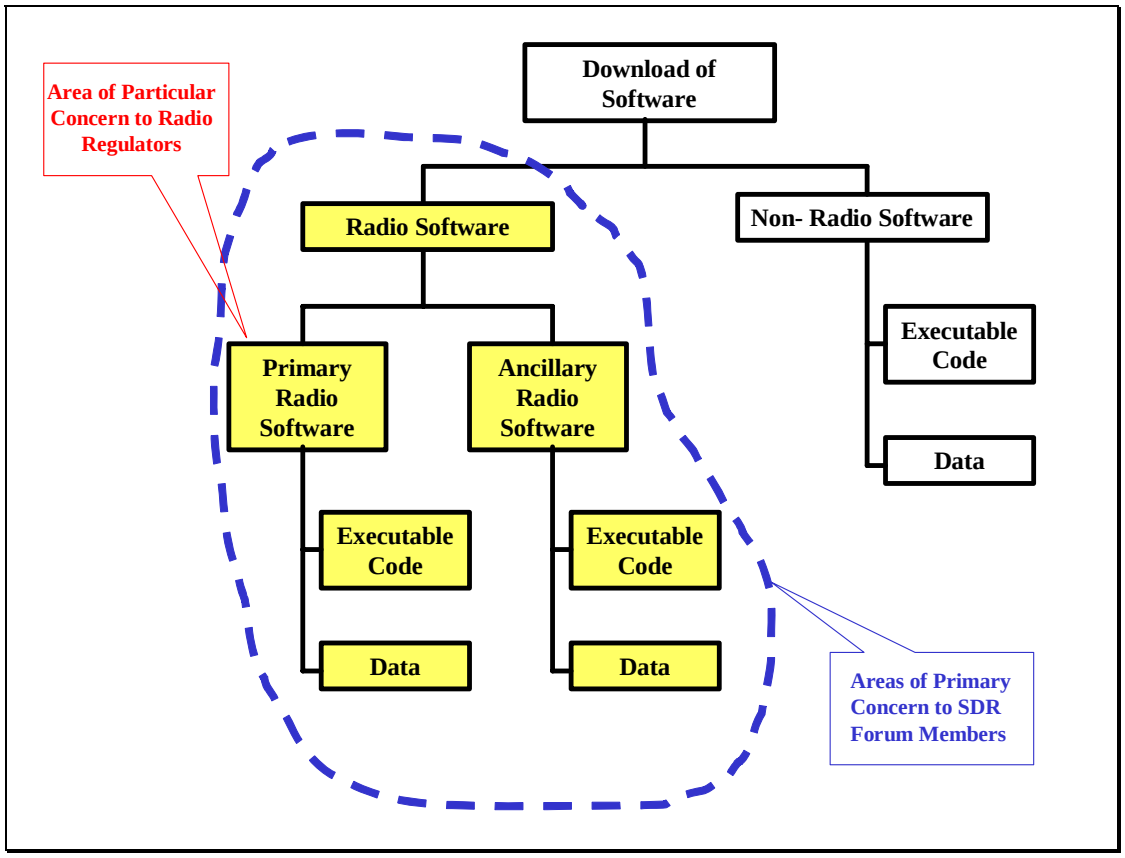

Figure 2. Characterizations of Software Download

[6] Undoubtedly there may be other characterizations. However, as noted above, these are the categories that are important in the context of this series of SDR Forum documents on software download.

For the purpose of the SDR Forum series of download documents, download of software can be divided into two main categories:

1. Download of software that reconfigures radio or network connection aspects of the device (referred to herein as *radio software* download), and
2. Download of software that does not affect these areas, such as user applications (referred to herein as *non-radio software* download).

In the SDR Forum series of download documents, the focus is on the radio software download rather than the non-radio software download. However, to the extent that some of the security, authorization, and authentication techniques used for non-radio software download (e.g. credit card transactions) may also have applicability to the radio software download, non-radio software will not be entirely ignored.

Radio software may be further divided into *primary* and *ancillary* software. The word "primary" in this context means software that affects the radio functionality (e.g., frequency, power, and modulation). The primary software within a wireless device is tightly coupled with the radio hardware to derive the overall radio functionality. By contrast, the word "ancillary" in this context refers to radio software that affects the use of the device, but does not affect the radio functionality. Input/output drivers and user interfaces are examples of ancillary radio software download.

An additional distinction is between downloading *executable software code* or *data* for use by executable code. This data may affect either the configuration of the SDR device or only user applications that do not have any impact on the configuration of the SDR device.

Two additional aspects of Figure 2 are of note:

1. The SDR Forum is primarily interested in the functionality that is enclosed by the dashed line. However, the Forum does have interest in the download of non-radio software because some of the security, authentication and authorization techniques already developed for download of non-radio software may also be applicable to the download of radio software.
2. Although regulators have the most concern about the download of "primary" radio software, regulators may also have some interest in the download of "ancillary" radio software as will be further explained in Section 6.2.

Examples of each type of software are provided in Table 1.

Table 1. Examples of Types of Software Download

Type of Software	Examples
Primary radio software executables (program code)	♦ New computing and communication software ♦ New air interface to implement a new standard (inter-standard adaptation) ♦ Air interface modifications to implement different features (e.g., increased bearer data rate) specified within a standard (intra-standard adaptation) ♦ Incremental enhancements (module or entity replacement) ♦ Patches for software bug-fixes
Primary radio software data	♦ Parameters that change the radio operational characteristics (e.g., frequency, power, and modulation parameters) ♦ Acceptable emission masks
Ancillary or supplemental radio software executable code	♦ Radio software download may also affect the control functions of the SDR device ♦ New user interface (look and feel) ♦ I/O Drivers (non RF related)
Ancillary or supplemental radio software data	♦ Reference database information, e.g., locally available services and operators (including capability exchange) ♦ Licenses to activate downloaded applications upon verified receipt of payment
Non-radio software executable code	♦ Programs that permit searches for restaurants in the area, stock analysis programs, MP3 player, etc.
Non-radio software data	♦ Voice packets and application data such as credit card information, stock market data, MP3 music files, etc.

5. Radio Software Download Scenarios

Table 2 presents a list of example scenarios for radio software download. There are different security, authorization, authentication and other related considerations associated with each of the scenarios. For each scenario, one or more examples are provided. The download scenarios in the table are characterized by:

1. The download environment: local or remote;
2. When the change software change is activated: immediate switch and activation of software or later reconfiguration;
3. How the download is initiated: initiated by the network, application or user.

"Local" download includes download methods such as attached cable, infrared, Bluetooth, technician at a kiosk, etc. Local download does *not* include download over the radio interface. By contrast, the remote environment software download is over-the-air via the actual radio interface in the device through the supporting core radio network. Scenarios 1-6 are examples of remote download scenarios, while Scenarios 7 and 8 are examples of local download scenarios.

After the software is downloaded, the software change may be activated immediately or at a later time. Software activation is a function of user and operator interactions associated with the software download process.

The download process may be initiated by the network operator, the user, or an application. For example, the network operator may initiate the action to update the capabilities of a terminal or for a bug fix (analogous to updates to virus-checking software in personal computers or to automatic updates of Internet Service Provider software). The user may initiate an update if he or she decides to access a new service. The application may initiate the update if, for example, the application senses that a new air interface module is needed based on previous user inputs.

Table 2. Download Scenarios

Scen -ario	Description	Examples
1	Remote Download of Air Interface Module and Immediate Mode Switch, Initiated by Application	Use of application code to make decisions of required air interface software, based on user profile inputs. Application code then requests appropriate download and completes download in an automated manner, and completes mode switch. This may involve negotiation between application software that has a user's profile and the network, based on the user's general profile and resources available on the network. This may or may not involve a hard hand-off. As an example, the initial network negotiation and download may be done by a cellular network (e.g., GSM) and require an immediate mode-shift and hard hand-off to another network.
2	Remote Download of Air Interface Module (for Later Reconfiguration), Initiated by Application	Use of application code (profile application code) to automatically translate user's general profile to download Air Interface Module software for subsequent use. May involve negotiation between application software that has a user's profile and the network.
3	Remote Download of Air Interface Module and Immediate Mode Switch, Initiated by Network	Switch air interface standard to adjust data pipe to appropriate bandwidth, possibly based on limited bandwidth availability or QoS considerations. Hard hand-off between modes may be required while transmitting data.
4	Remote Download of Air Interface Module (for Later Reconfiguration), Initiated by Network	Download SDR software, upgrading from version X to version X+1, but don't switch immediately. Could be general upgrade, or specific patches to fix problem in handsets.
5	Remote Download of Air Interface Module and Immediate Mode Switch, Initiated by User	Switch air interface standard to request specific type of service (i.e. higher bandwidth), or for new air standard based on travels between areas with different air interface standards and service providers. This may require interaction between the user and network as user directly negotiates availability of certain standards with the network. This does not require interaction with application that carries user's profile – user's request is adequately specific to bypass a profiler application. This may or may not require hard hand-off between modes while carrying traffic.
6	Remote Download of Air Interface Module (for Later Reconfiguration), Initiated by User	Download air interface standard in one country before travel to another, but do not make immediate shift of air interface standard (that step is initiated separately). This does not require interaction with application that carries user's profile – user's request is adequately specific to bypass a profiler application.
7	Local Download of Air Interface Module (for Later Reconfiguration), Initiated by Application	Application requests loading of specific air interface module, based on previous user inputs. Terminal cannot initially join cellular session because it is not configured to do so. Application must request download of air interface module via connection to computer, via card or via default wireless standard (like Bluetooth).
8	Local Download of Air Interface Module (for Later Reconfiguration), Initiated by User	User requests loading of specific air interface module. Cannot initially join cellular session because terminal is not configured to do. User must download air interface module via connection from computer, via card, or via default wireless standard (like Bluetooth).

6. Radio Software Download Considerations

6.1 Download Technical Considerations

This section provides a high level overview of technical aspects of software download that must be considered. The more detailed technical requirements in this regard will be provided in the SDR Forum Document DL-REQ, "Requirements for Software Download for RF Reconfiguration."

6.1.1 Functional Considerations

The following is a list of questions that need to be addressed as functional considerations during the process of developing detailed requirements for software download for RF reconfiguration. Many of these functional considerations have both radio and network aspects. For example, capability exchange, authentication and authorization all invoke elements of the wireless network as well as the SDR-capable device (i.e., terminal or base station).

- Who will be the users and how easy will it be for them to download the software? (usability)
- Who makes the decision to download the software?
- How is the download destination(s) determined?
- Will the terminal function on other networks with different air interfaces? (roaming support)
- Does the destination terminal have the technical capability to correctly run the software?
- How is capability exchange implemented (i.e., what negotiation with the network or other device as to the waveform and protocol is used for communications)?
- To what extent are modules to be common and transferable across platforms? (plug and play)
- What backward compatibility considerations have been made?
- What security mechanisms are used?
- What authentication of the software module, the hardware module, the user, and the organization is used?
- How is access controlled? What are the access control parameters (protocol, integrity checks, authentication of downloaded data, encryption parameters, etc.)?
- How is the integrity of the downloaded code verified?
- How is configuration management accomplished?
- Are low probability of interception and detection techniques incorporated and are they needed?
- What protocol support is used? Is it recoverable, redefinable, and what of the instruction set does it recognize?
- What techniques are implemented to ensure recovery?
- What types of information are required as part of the download protocol? Are memory space, load address, start address, length of the download code, and required libraries included in the download control protocol?
- What compression techniques are used for software download?

- What data types are recognized as part of the download protocol?
- Where is the code stored after it has been downloaded?
- How complex is the implementation and what is the impact of this complexity on cost?
- How is incremental upgrade accomplished? (i.e., does all the software have to be replaced or can just one block be replaced?)
- How is memory management accomplished for software download?
- How much traffic does each type of download generate?
- How much software download traffic can the network support? (network capacity)
- How long does each type of download take?
- How much energy is consumed as the result of implementing a software download capability (especially in terminals)?
- Is the software download extensible and scaleable?
- How is billing and licensing of the download code accomplished?
- Who owns the software?
- What liabilities are attached to the use of the download software?
- Who is responsible for maintenance?
- Can the download process be used to deny service?

As noted, a subsequent SDR Forum report will provide detailed descriptions of specific requirements generated by the high-level functional considerations listed above.[7] The requirements addressed by that document will include specific download protocol requirements.

6.1.2 Software Download Considerations for the Radio

Much of the focus of SDR and radio software download to SDR-capable devices has been on the radio (i.e., the terminal or the base station). Obviously, the terminal or base station must have adequate programmable processing capabilities for software download to be feasible at all. For the present, radio considerations for radio software download are related to underlying core technologies such as hardware technology (RF enablers and digital processing enablers) and software technology.

Figure 3 is a generic SDR functional block diagram. For simplicity, only the transmit side of the radio is depicted. The key aspects of the SDR-capable device are the processing engines (i.e. programmable DSP chips, etc). The processing engines depicted in the figure are:

- Signal processing engines, which operate on the radio signal itself (e.g., RF front-end signal processing and baseband signal processing engines); and,
- The software control-processing engine.

[7] SDR Forum Document DL-REQ, "Requirements for Software Download for RF Reconfiguration".

The software signal-processing engine essentially provides a means for processing of the information signal in either programmable or reconfigurable, hardware. The software control-processing engine provides the control over the SDR-capable device configuration in response to either inputs from the user or from control signals from the network. Figure 3 is the embodiment of the radio implementer's plane that was depicted in Figure 1(see Section 2). For software download, the capabilities of the SDR-capable device must be communicated to the network as part of the capabilities exchange.

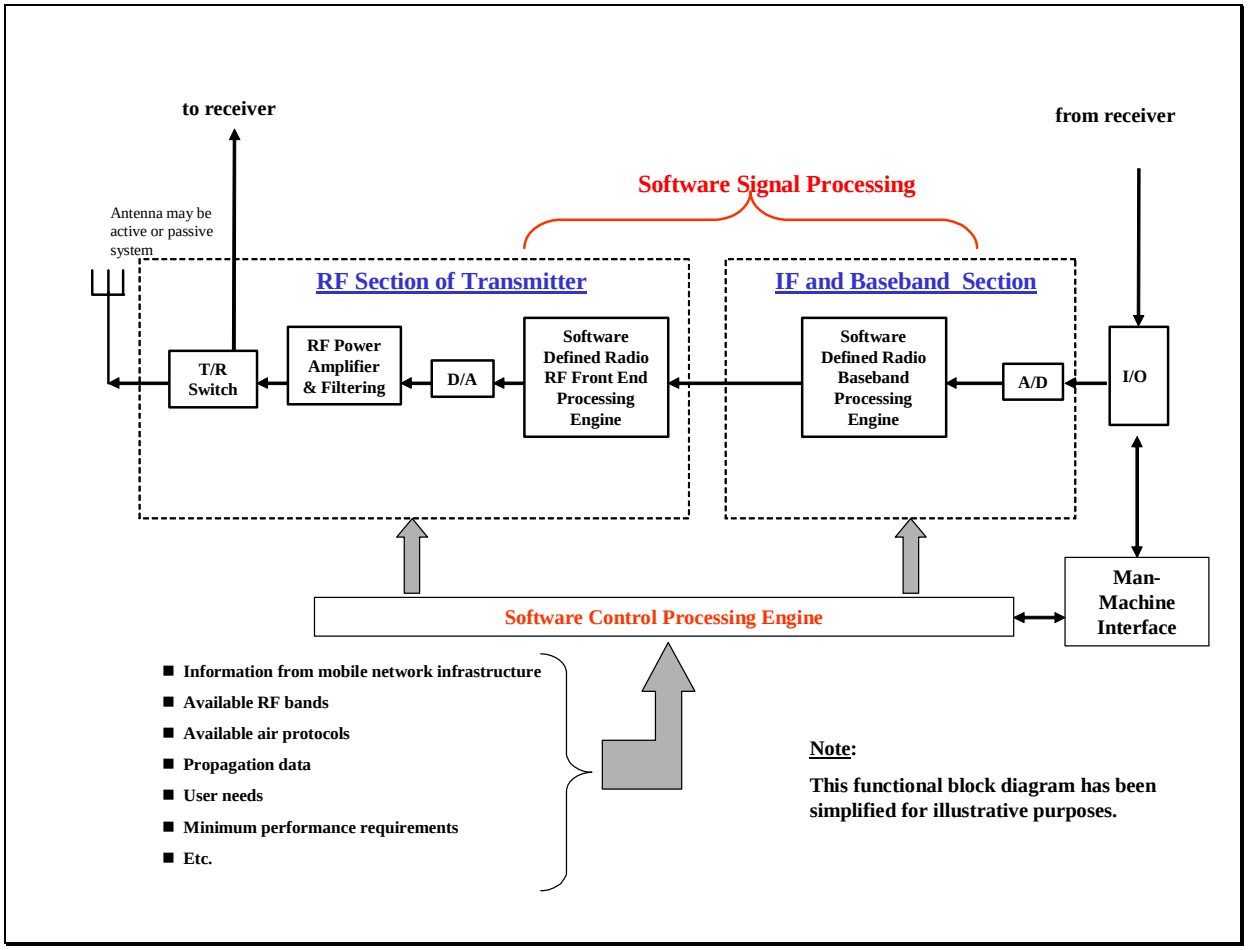

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Figure 3. Software Defined Radio Concepts

6.1.3 Software Download Considerations for the Network and Radio Control

Some software download capabilities exist today, but they tend to be terminal centric. Furthermore, they tend to be minimally focused on radio software download (if at all) and more focused on non-radio software download or service authorization mechanisms. Ultimately, the full benefits of radio software download require a system solution that involves both the network and the terminal.

In commercial wireless service, one common scenario involves:

- The need to identify alternative communication modes; and,
- The need to negotiate the most appropriate communications mode based on the user's service requirements and the cost-of-service restrictions, as well as quality of service preferences based on the user's profile or network operator.

Together, this gives rise to the need to download the appropriate software modules to either a terminal or base station to satisfy the user's requirements and preferences.

For the scenario above, the interaction of the network and its base stations or terminals is integral and tightly coupled. For example, there will in all probability be interaction between network elements and the target of the software download (terminal or base station), especially for the following: authentication, capability exchange, billing and licensing of software, roaming and access control functions.

In an over-the-air download scenario to a terminal, there are databases within the network that might be accessed as part of the radio software download process, and control of the process resides within the network. Other forms of download (such as within a system to a base station) may have their own unique requirements and databases.

This scenario outlines many of the elements of the network that should be represented in the development of radio software download protocols. This includes what might be considered to be the radio control. For example, to implement capabilities such as negotiation for the most appropriate communications mode, the control signaling present in current commercial wireless systems would need to be extended as part of defining any download protocols.

In addition, software download generates additional traffic that is not directly revenue-generating information traffic for the operator. This additional load must be taken into consideration when designing new download capabilities into the system.

6.1.4 Standardization Considerations

The following are some standards considerations that will be discussed in other SDR Forum Documents related to download:

- What level of standardization is required to ensure regulators that security concerns related to software download affecting radio parameters have been adequately addressed?
- What is the minimum level of standardization required to ensure that SDR devices can communicate (download) within a number of radio environments, yet allow manufacturers, operators, service providers and independent software developers the flexibility to innovate within their field?
- Will standardization be required to address billing, licensing, ownership, and security considerations for downloaded software?
- What is the likelihood and what are the implications of *de-facto* or *de-jure* standardization?

The first item in the list is of particular importance to regulators and will be addressed in specific reports being prepared for the United States FCC. These reports, although addressed to the FCC, will be globally applicable to regulators in all regions of the world.

6.2 Radio Software Download Regulatory Considerations

Initial regulatory inquiries, can be partitioned into four broad categories:

1. Regulatory monitoring of the state of technology
2. Interoperability between radio services
3. Spectrum efficiency and sharing
4. Equipment approval process

Initial awareness of SDR in the regulatory community often occurs because of the great potential benefits to interoperability and spectrum efficiency the technology promises. The first inquiry of regulators is with regard to state of the technology; that is whether or not it is sufficiently close to market deployment to impact their regulatory sphere of concern. Once the market deployment status of SDR has been ascertained, other focal areas may include:

- Existing regulations that may present a barrier to SDR deployment;
- SDR's potential implications for existing spectrum users.

Figure 4 is a regulatory view of the multi-dimensional aspects of SDR. Initial regulatory concern will largely be focused on the lowest level and the protection of radio spectrum. This was demonstrated in the United States FCC proceeding history. After investigating a broad range of potential regulatory involvement including interoperability between radio services and spectrum

efficiency and sharing, the Commission concluded that at this time only rule changes to the equipment approval process were needed.

The "higher-planes" concerns, however, are seen to become important later on as SDR technology matures and becomes more widely adopted. This is evident in Figure 4, which shows how the regulatory concerns related to radio software download can be viewed as an evolving process that focuses for the time being on equipment certification considerations. The concerns are:

- How will type approval be applied to terminals capable of reconfiguration via software developed by independent third parties?
- Must all hardware and software be type approved?
- What controls are in place to ensure that SDR devices are not susceptible to malicious attack?
- Will industry deploy adequate security mechanisms for ensuring that radio parameters (e.g., frequency, power, and modulation) cannot be changed by unauthorized users?

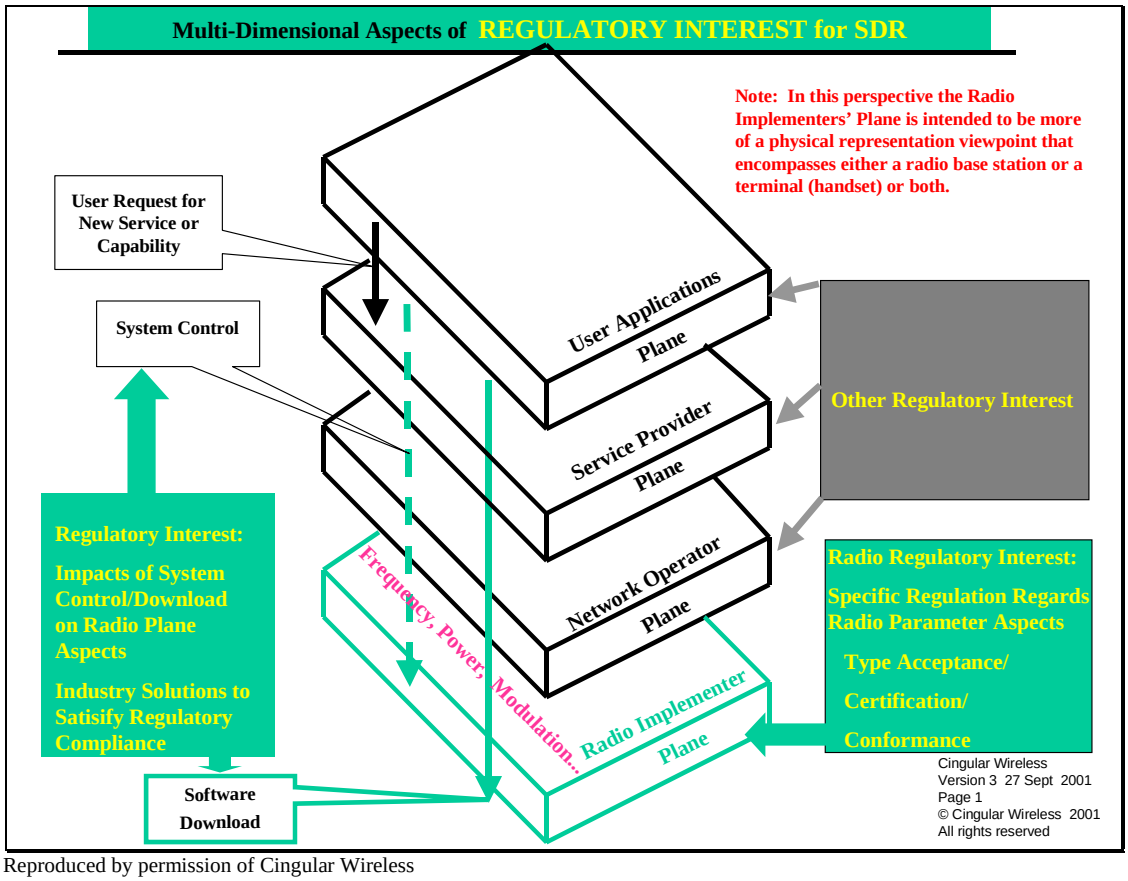

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Figure 4. Evolution of Regulatory Concerns

There are also some considerations that arise regarding certification and type approval. Historically, type approval has been applied to specific terminal equipment containing resident fixed software. When software download is considered, the personality, behavior and performance of the terminal can be modified. Some questions to consider are:

- Must all software applications and all hardware platforms be separately type-approved?
- How can type approval be guaranteed for any type-approved software application running on any type-approved platform?
- How should billing, licensing (both time-domain and geographical) and ownership of software be handled?
- How can regulation protect against malicious intent (e.g. software viruses)?

6.3 Coordination Amongst Download Stakeholders

The roles and responsibilities in the software download process must be defined for users, network providers, service providers, application providers and terminal manufacturers. For example, this includes the responsibility of manufacturers to inform the network operators when changes are made that may impact network operations.

A process for the near-term coordination amongst download stakeholders is provided in Section 7. The SDR Forum has been, and will continue to be, the organization that will serve in a focal-point role for software radio, particularly with regard to requirements development and interaction with regulatory agencies.

7. Download Considerations

There are many considerations that must be understood related to the full scope of radio hardware, radio software, and download of radio software. These considerations include the relationships between the hardware and software and any requisite testing, conformance, certification or type acceptance. Furthermore, the actual process of download and subsequent issues must be fully understood and characterized.

7.1 Radio Software Download Methods

A number of methods for downloading radio software to a SDR device can be envisaged. For example, the method of download may be:

- Via SIM-card or other removable media, which contains the software to be downloaded and which may also contain a pre-paid license to use the software and stored user preferences and security tokens;
- Via wireline local or remote host server, via modem and fixed network (e.g. telephone or cable service);
- Via handheld field device;
- Via CD-ROM or Internet/Intranet, using a personal computer;
- Via kiosk or street-side terminal (e.g., download to SIM card via an Automatic Teller Machine (ATM));
- Via multiple devices using Bluetooth;
- Via Point of Sale terminal in a shop or service center;
- Via wireless link (i.e., over the air). Both point-to-point and point-to-multipoint (broadcast) options could be used. In a commercial situation, the download server could be provided by the service provider, utilizing the network operator's airtime resources;
- Via transfer between user terminals.

The above examples are primarily for SDR-capable terminals. Download applies to base stations as well. Each of the above download methods implies a different combination of originator, source and end-user characteristics. Security needs will vary depending on the method used to download software to a specific SDR-capable device.

7.2 Download Implementation

There are a number of specific implementation consideration associated with radio software download of executable code and parameters used by that code including:

- Where to put the code once it has been successfully downloaded (file, flash memory etc.);
- What specific download instructions are required (load address, start address, lengths etc.);
- What data types are allowed.

In addition to the above, radio software download for SDR terminals could be either centralized or decentralized [reference 1]. For example, in a decentralized scheme, the software could be

downloaded either directly to a terminal from the server, or it could be downloaded indirectly. For indirect software download, the software is initially downloaded from the server to a terminal that in turn downloads it to other terminals.

7.3 Radio Hardware and Radio Software Combinations and Associated Considerations

Software can be downloaded to change the software in the radio or to change the hardware configuration in cases where the signal processing is implemented in FPGAs. The following radio hardware and radio software combinations must be considered:

1. Initial radio hardware and radio software set tested together at time of initial manufacture with radio parameters "established" at time of manufacture. This may be viewed as the baseline case where the initial type approval, type acceptance, conformance declaration, etc, is done as a closely related part of the initial product. The question to be asked here is: is this a "business as usual scenario?".

2. Initial radio hardware and *revised* radio software post manufacture emplaced in device via download

3. *Revised* radio hardware and *revised* radio software

Scenarios 2 and 3 may be viewed as one aspect of SDR that takes advantage of the flexibility post-manufacture and must be characterized and a list of considerations developed related to download of radio software.

7.4 Radio Software Download Stages

In understanding download at the highest level, it is convenient to consider how the download can be subdivided to provide a perspective of analysis. One high level view of this is to consider three distinct stages:

1. Pre Download (preparatory)
2. During Download (procedural)
3. Post Download (installing)

Each stage has a set of concerns that must be addressed both individually and collectively.

The Pre-Download Stage might be considered to have a certain measure of controllability in that the target SDR device can be queried and communicated with. It should be possible to fully understand the security and integrity of the radio hardware and software in current configuration. The Pre-Download Stage consists of events that occur prior the actual download of radio software to the SDR device, such as:

- Service discovery;
- Mutual authentication;
- Capability exchange;
- Download acceptance exchange.

The During-Download Stage has implications for what must occur as information is conveyed to/from the target SDR device. Events that may occur during this stage are:

- Physical transfer of the software to the SDR device;
- Verification of the integrity of the downloaded software;
- Retransmission requests.

The Post Download stage has implications for what steps must be developed for ensuring that "all is well" and that the downloaded information meets certain criteria. This stage consists of events such as:

- Installation of software;
- In-situ testing;
- SDR device reconfiguration;
- Non-repudiation exchange;
- Recovery efforts.

7.5 Implications and Tasks

As can be seen, there are many areas that require further definition and development in the domain of radio software download. These include developments in the testing of radio hardware and radio software combinations. They also include developments of download standards for radio software that will be globally accepted and commonly applied across differing radio air interfaces and core networks to address the combinations (revised software or revised hardware/software), the environments (local or remote), and the three stages (pre, during, and post download). Fundamentally, we are seeking answers to these three questions:

- How do the combinations, environments and stages relate and cause the download solutions to be altered or different in design and definition?
- What are the required standards?
- What are the protocols, processes and procedures?

8. Summary and Next Steps for Globalization of Radio Software Download Activities

This document is the first of a series of SDR Forum documents on radio software download vision, requirements, and regulations. This document provides the overarching view of the SDR Forum perspective on radio software download for SDR-enabled devices. Achievement of the long-range objectives for SDR requires the close global collaboration of manufacturers, network operators, services providers, regulators and proxies for the user community, especially in the area of radio software download. To achieve this global collaboration, the SDR Forum envisages the collaborative structure for radio software download depicted in Figure 5 (on the following page).

The left portion of Figure 5 depicts what might be considered to be Phase I of SDR activity. Interest in software defined radio started in about 1995. Between 1995 and 2001 there was growing interest in SDR as evidenced by the increased number of publications on the subject [see the references, for example] and by the fact that SDR products began appearing for both commercial wireless applications and for military communications systems. During 1999, the SDR Forum began having informal interactions with the Federal Communications Commission. These discussions led to the first-ever regulatory body decisions on SDR. The SDR Forum also completed some initial informal papers on SDR requirements. In addition, the SDR Forum began formal interactions with the Mobile Execution Environment regarding download requirements. This was the beginning of the formal globalization of SDR Forum outputs.

The right portion of Figure 5 depicts the SDR Forum's aggressive program for the globalization of SDR download work in regard to both international standardization of radio software download requirements and protocols and for the globalization of regulatory activities.

Attaining the twin goals of (1) completion of global standards on radio software download (including security), and (2) completion of the second phase of SDR regulations (including global coordination) will require close cooperation between the SDR Forum and relevant external organizations as well as global regulatory entities. In collaboration with the relevant external organizations, the SDR Forum must rapidly complete technical radio software download standards requirements, and then the technical standards/specifications governing radio software download that satisfy these requirements. Government regulators are looking for this work to be done by industry rather than imposing these criteria on industry. For this to be realized, dialogue must be maintained between the Forum, the regulators, and the other relevant external organizations as depicted in Figure 5.

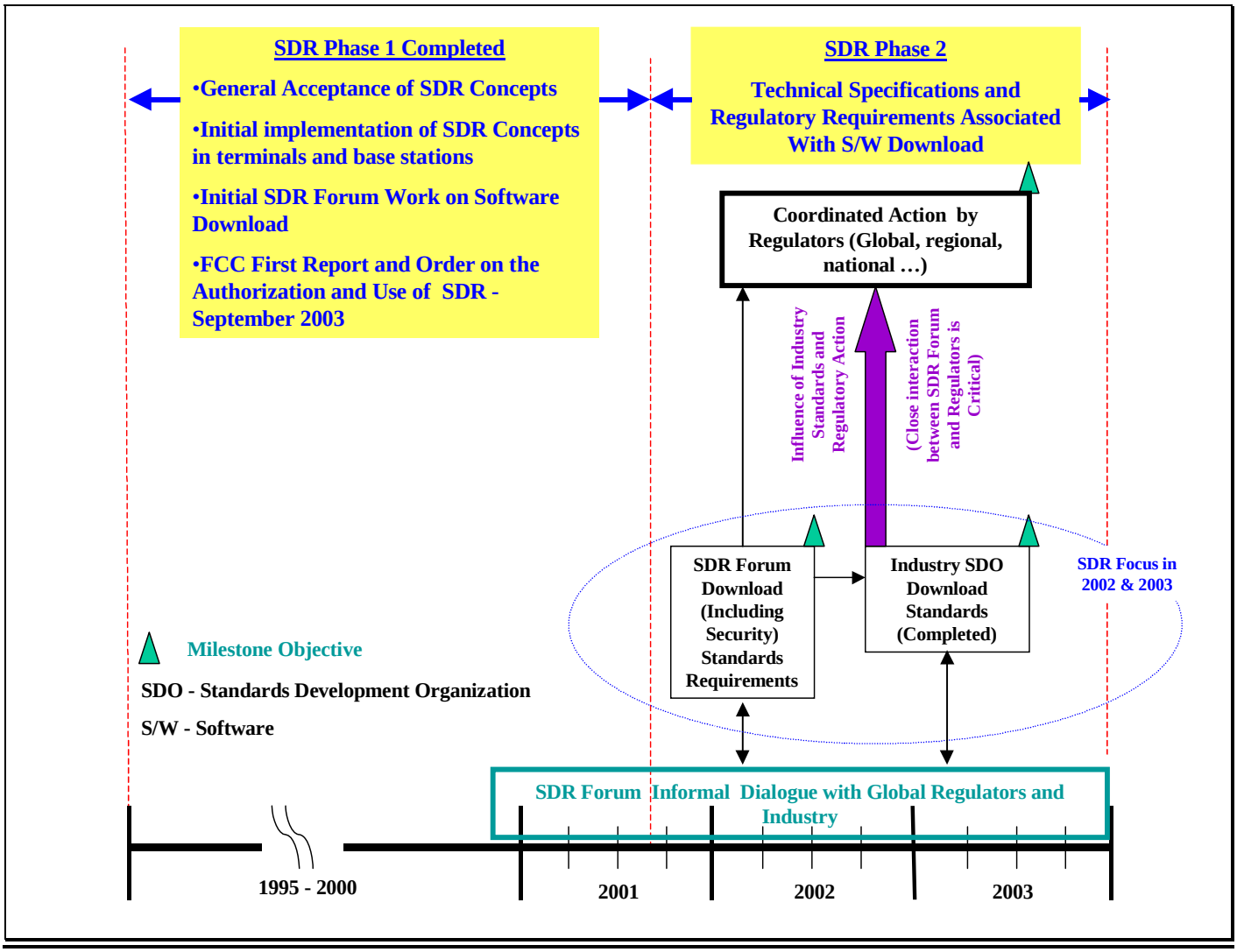

Figure 5. SDR Forum Work Management Relationships

9 References

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