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A plan-driven dynamic reconfiguration mechanism for C2 Communities of Interest

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Abstract

A Command and Control Communities of Interest (C2COI) is a dynamically formed military organization or community for a common mission in net-centric operations, composed of distributed command and control entities (infrastructures, systems, equipments, weapons, and forces, etc.). C2COIs should be organized rapidly and reconfigured dynamically to adapt to the unexpected events and dynamic changing in the complex operation environment, which requires not only the organization form and force structure more flexible, but also the military information systems construct agilely and reconfigure self-adaptively. In this paper, a plan-driven dynamic reconfiguration mechanism for the C2COI is developed called C2COI System Support Plan (C2SSP), which establishes a mapping from the controlled entities to the command and control information systems, forming the basis of self-adaptive reconfiguration.

After depiction of the conceptual model of C2SSP, its descriptive model is presented through various views of communication assurance, information exchange, data-sharing among systems, and physical/logical deployment, service organization, user interface integration, process description within systems, with the dynamic reconfiguration mechanism based on C2SSP proposed in the end.

Keywords： C2COI, Operation Plan, C2SSP’s Descriptive Model, Dynamic Reconfiguration

1 Introduction

Following the Network Centric Warfare (NCW), Communities Of Interest (COI) is another concept related to net-centricity. A COI can be classified into two broad categories: institutional and expedient. The former has an organization with long-term static members, while the latter refers to a comparatively temporary organization or group established for a specific common task or mission and remains in existence only for the period of time required to complete the task. Particularly, C2COI is a special kind of expedient COI, which is composed of various operational forces including C2 entities and equipments (units, sensors, weapons and platform systems, etc.) distributed broadly and attached to different military organizations. It combines various forces rapidly and agilely according to mission requirements across system boundary, following a certain organization structure, function,

and mission assignment.

C2COI is featured with self-organization and self-adaptation, as it can organize and manage the controlled entities according to the task and members' responsibilities or rolls, establish their relationships, decide the cooperation patterns, organize and construct the component elements self-formingly in a consistent order across space, time and function. Its unit organization (UO) structure should be flexible, robust and agile, and the information systems of the controlled entities within it should be able to reconfigure adaptive to the unit organization structure's changes.

As C2COI is an important organization form of joint operation in NCW, its organization planning and execution management must be a crucial element of operational plan (OPLAN). Normally, OPLAN is used to specify the organization and behavior of persons (units) involved in the task, which is focused on person, with unit organization as one of its core elements. When the unit organization is decided, how to modify the information system's information exchange, data-sharing, interaction and cooperation relationships adaptive to new relationships between the troops, how to prune, allocate and reconfigure the internal function modules of C2 systems, and how to define and adjust C2 processes dynamically, has to be scheduled uniformly and adjusted dynamically before the action taking or system running. In this paper, the concept of C2COI System Support Plan (C2SSP) is proposed, based on which, a plan-driven dynamic reconfiguration mechanism for the C2COI is developed.

2 C2SSP Conceptual Model

C2SSP is a kind of system support plan which prescribes the organization structure, capabilities and behaviors of systems according to the unit organization represented in the operational plan, in order to accomplish system's automatic configuration, dynamic reconfiguration and sequential execution. The conceptual model is shown in Figure 1.

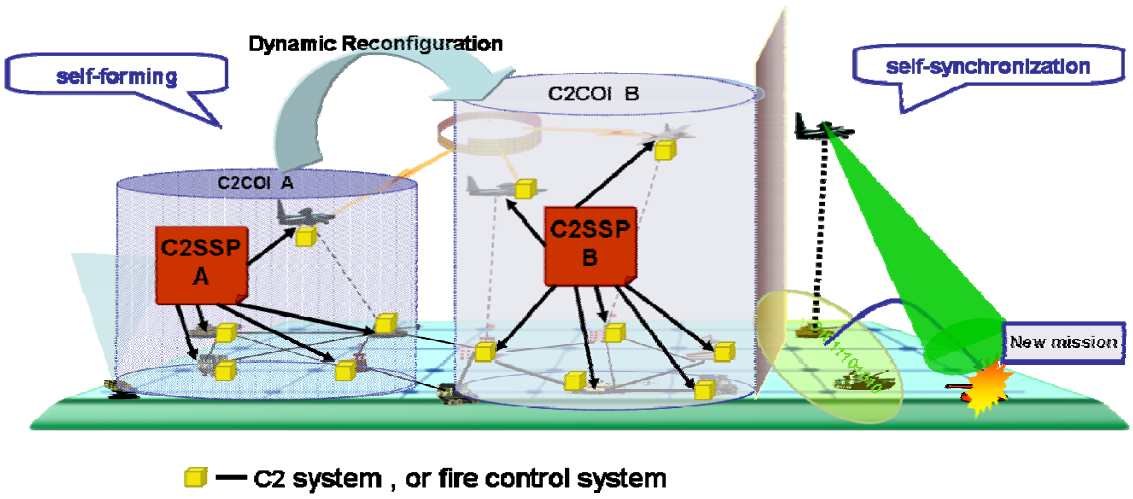

Figure 1. The Conceptual Model of C2SSP

As a complement of the existing OPLAN architecture (on system and equipment planning), C2SSP in its essential, is to realize self-forming reconfiguration of C2COI through constructing the command and control information systems flexibly by definitive and descriptive methods. C2SSP joins the OPLAN and system equipments seamlessly, forming a map from the troops to the information systems in C2COI.

Definition:

$$\delta : U \to S$$

where： U: refers to C2 entity space (troops or units, platforms, and weapons).

S: refers to controlled entity space (C2 systems and fire control systems).

δ : refers to the mapping from U to S， i.e. C2SSP.

The concept of C2SSP is proposed based on the following prerequisites:

- C2 unit organization is one of the core element of C2COI, which focuses on the relationship of units and the assignment of equipment resource,
- The C2COI organizations have worked out an operational plan or unit organization plan,
- The C2 system is robustly networked, ability-based, and task-oriented,
- The C2 system is based on Service-Oriented Architecture, whose constitutor services may be registered internal ones or the authorized external ones distributed on network, and
- In this paper, the reconfiguration focuses on system integration level.

3 C2SSP Descriptive Model

3.1 Descriptive Model

The descriptive model of C2SSP is described in sets.
Definition：

C2SSP is a set named CP, and $CP = A \bigcup E \bigcup R \bigcup S$.

where：

- Set A is the description of C2SSP's basic attributes and profile information, including identification information, planning time, planner, involved mission and the attached C2COI's ID.

  A = {Plan name, Plan ID, Planning time, C2COI, Planner, ...}.
- Set E is the system organization and mission assignment according to the C2COI's

$E = \{e_i \mid e_i \in S_{sys}, i \in N\}$.

S_{sys} = { System name, System ID, Attached unit, Support mission, Running state, Time to set up, ... }.

- Set R describes the relationships between systems present in set E, including communication assurance, information exchange and data sharing relationships, in which, the information exchange subset is consistent with the system-system matrix described in DoDAF2.0[4], including the information elements to exchange, attributes of elements, and attributes of the exchange:

  $R = M \bigcup D \bigcup C$

  Where:

  $M = \{m_i \mid m_i \in S_{\inf}, i \in N\}$.

  $S_{\inf}$ ={ source system ID, destination system ID, information type, information format, transport protocols, exchange frequency, encrypt requirement, ...}.

  $D = \{d_i \mid d_i \in S_{dbs}, i \in N\}$,

  S_{dbs} ={ system ID, database server IP, database SID, user name， user password, database service URL, ...}.

  $C = \{c_i \mid c_i \in S_{cmu}, i \in N\}$,

  S_{cmu} ={ communication channel requirement, link control protocol, transport protocols, gateway, Router ID, port, ...}.

- Set S is the key element of C2SSP, including structure and deployment information about C2 systems in set E, such as deployments of clients and servers, reconfiguration of software and predefined processes of command and control.

The Descriptive Model of C2SSP is shown in figure 2.

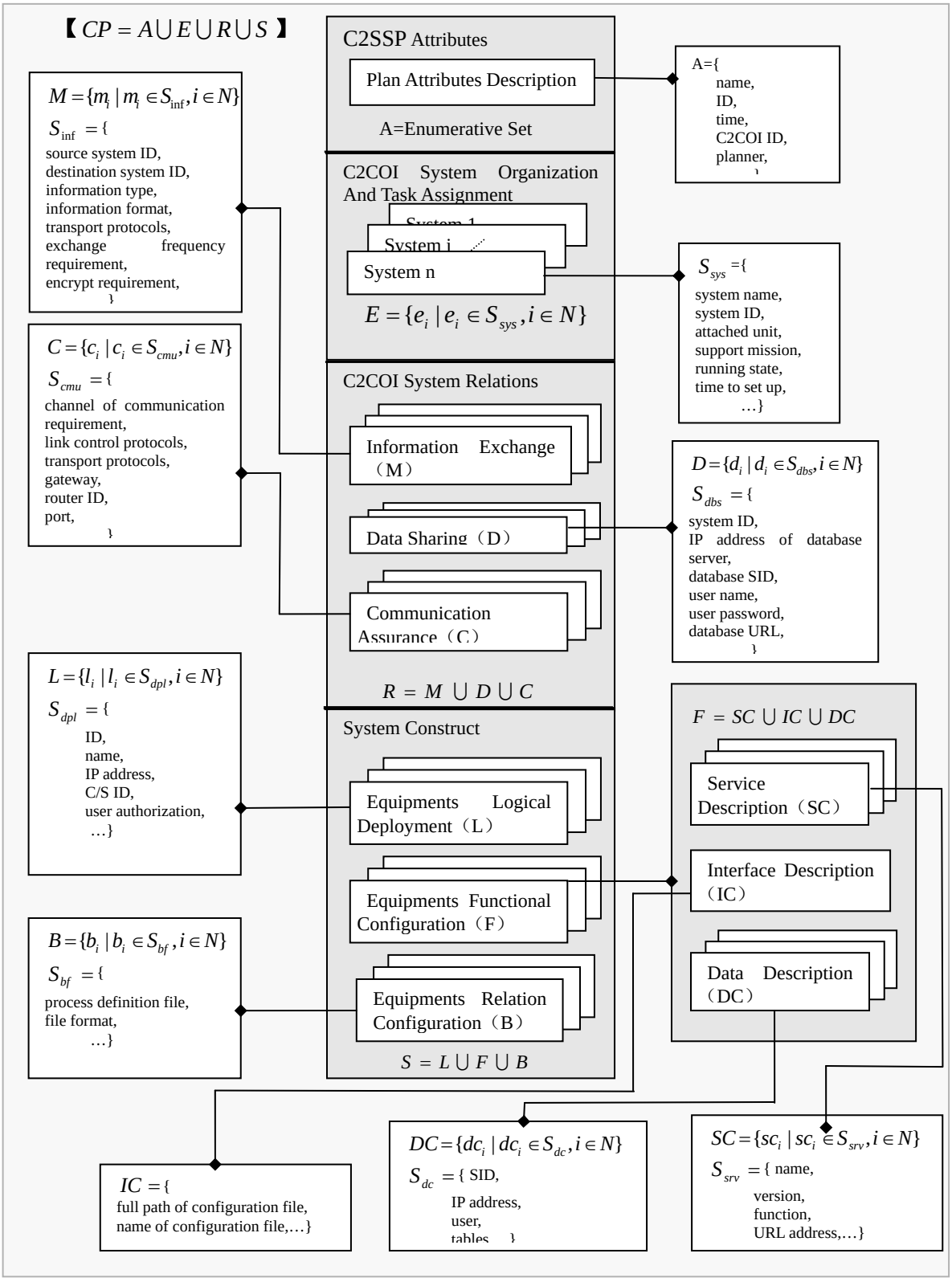

Figure 2. The Descriptive Model of C2SSP

Following is the explanation of set S in Figure 2.

Define:

$S = L \cup F \cup B$

Where:

1) Set L—— logical deployment of all the system equipments (maybe seat, server, or fire control unit etc) in a system. According to the task assignment and the operational course, each seat or control unit all has its own responsibilities and working patterns. So, on setting up a system, firstly deploy seats, servers and fire control units, and configure and manage users uniformly.

$L = \{ l_i \mid l_i \in S_{dpl}, i \in N \}$

S_{dpl} = { equipment ID, equipment name, IP address, equipment type, configuration of user authorization,...}

2) Set F——assembling and configuration of software, also a key to system elements dynamic configuration. As a core element of C2SSP, F is designed from these three aspects: data requirements, service choreography and user interface (UI) integration with output as various formatted files that can be automatically parsed and executed by relevant engine, so as to realize the dynamic configuration of system.

$F = SC \cup IC \cup DC$

Where, $SC = \{ sc_i \mid sc_i \in S_{srv}, i \in N \}$, is the set of services deployed on the equipment, including description of service and relationship between service and its UI. Services mentioned here, as described as enumerable type, may be services registered inside or outside the system.

S_{srv} = { service name, service version, service function, service URL, IP address, service type, transport protocols, the expected service response time, the page calling the service， the component calling the service, access to service... }

Set IC describes the UI interface representation and integration information, in specifically formatted configure file, including interface layout, definitions of interface manipulation and constrains, management of sessions, windows, processes and service calls etc.

Set DC describes the data requirement of the seat.

$DC = \{ dc_i \mid dc_i \in S_{dc}, i \in N \}$

S_{dc} = { data source SID, data source IP, user, password, tables, ... }

3) B——Definitions of system processes or business flow, describing the relations between seats or control units, including plan approval, plan circulation, cooperation

Above is the detailed description of the system construct factor S. Note that although the content is complicated, and requires the planner to be more professional and technical, in practice, plans are always generated from existing plans, and the course of planning is merely edition or adjustment to partial content of existing plans, with visualized planning tools available as support. So, the course of planning C2SSP is not complicated and is semi-automatic.

3.2 The Form of C2SSP and Its Planning Tool

C2SSP is composed of the plans in text format expressed in natural language, formatted files for exchange and some data files of plan element, as shown in Figure 3.

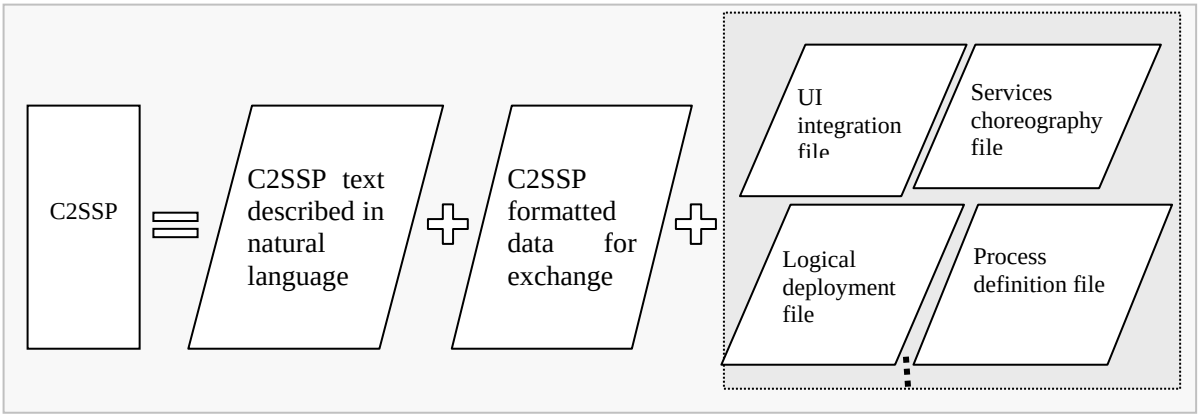

Figure 3. The Form of C2SSP

It is good practice to utilize some effective visualized planning tools to draw up the C2SSP, which can shorten the planning cycle, enable system construct rapidly, and allow a runnable C2COI to be organized within the least time, so as to achieve flexibility and agility in NCW. The planning tool of C2SSP must be able to:

- Integrate with OPLAN planning tools, exchange information with OPLAN planning systems, and parse the unit organization data in the OPLAN to provide a reference to system organization and task assignment,
- Provide graphical edit mode, so as to facilitate user deployment and configuration of seats, servers ,controlled units, user interfaces, and business processes,
- Offer a variety of views to show the relationships of system information exchange,

data sharing and the network communication assurance,

- Support management of multiple plan sets, and quick generation of new plans based on existing ones, and
- Generate various formatted data files mentioned in above.

One of the user interfaces in the developed C2SSP planning tool is shown in Figure 4.

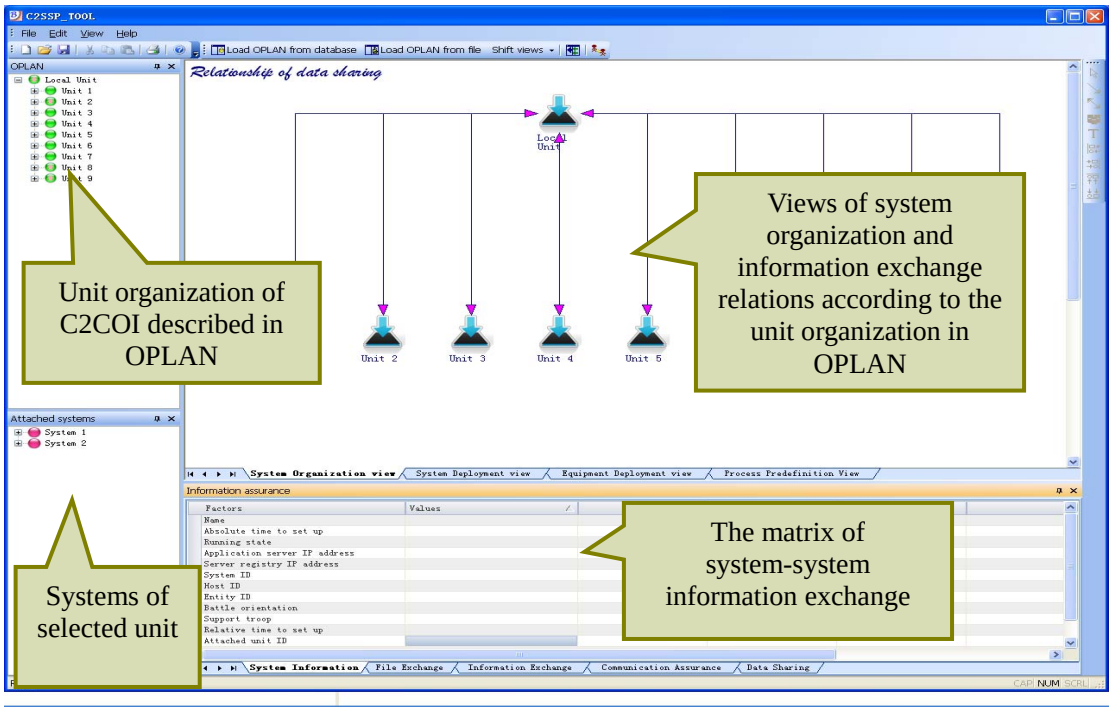

Figure 4. The part UI of C2SSP planning tool

4 Plan-driven Dynamic Reconfiguration Mechanism of C2COI

4.1 Closed Loop of the Mechanism

Based on the above C2SSP descriptive model, this section elaborates the implementation of the dynamic reconfiguration mechanism of C2COI. As is called plan-driven mechanism, it starts from OPLAN planning, and ends into a closed loop: OPLAN planning→C2SSP planning→C2COI system organization→system deployment→running→C2→planning/ adaptation→reconfiguration, as shown in Figure 5.

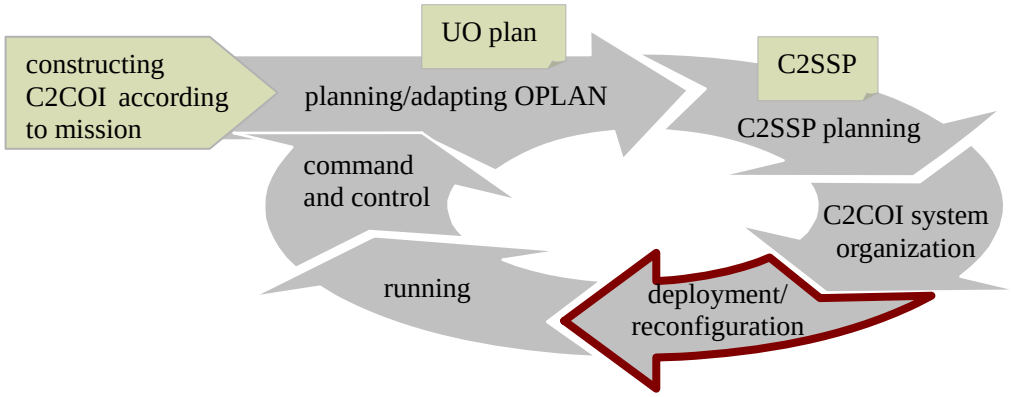

Figure 5. Closed Loop of the Mechanism

In the above process, as one of the C2COI elements, it is the first step of C2COI constructing to organize system according to unit organization and mission assignment, which is an organization process. The deploying and reconfiguration of each internal member system is automated by computer, as well as C2SSP execution.

4.2 Mechanism Implementation

The plan-driven dynamic reconfiguration mechanism for C2COI is described in figure 6.

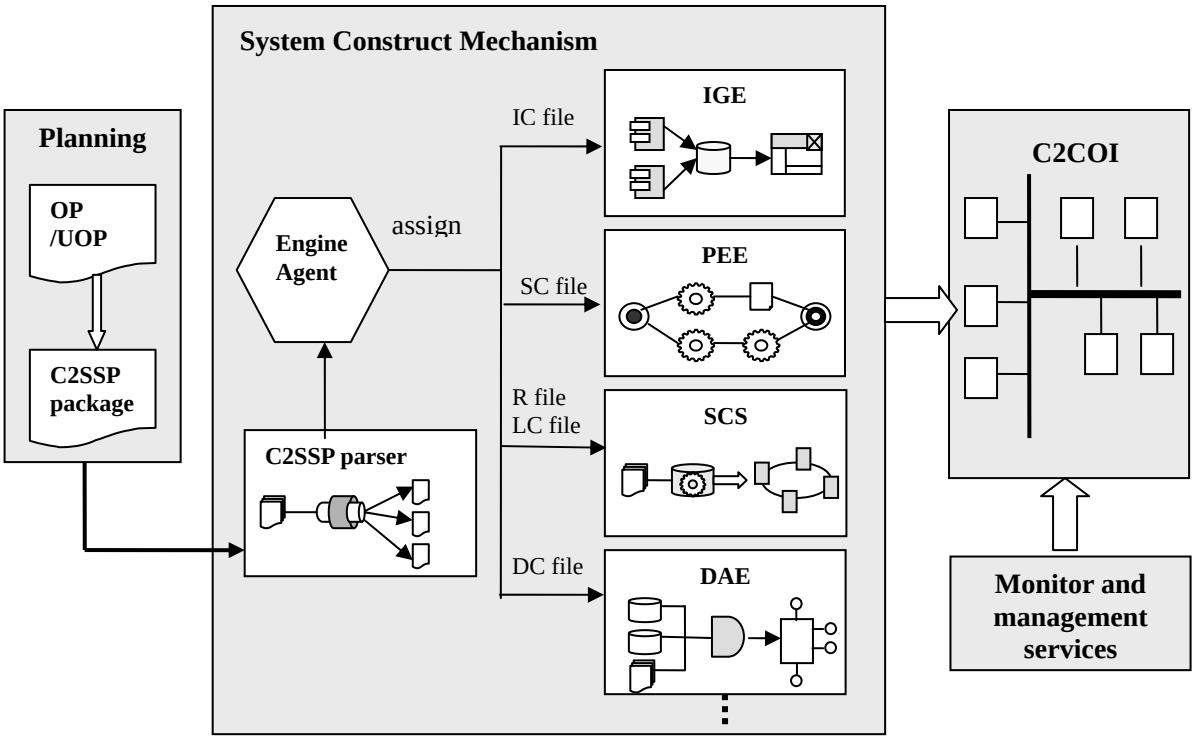

Figure 6. Implementation of plan-driven dynamic reconfiguration mechanism

The concrete process is as follows:

1）Draw the C2SSP based on operational plans or unit organization plans, package and

distribute it to each system in C2COI,

2）By receiving the C2SSP package, each system parse it using C2SSP parser, and decompose it into various configuration files required in system construction (See also Figure 2 for the descriptive model of C2SSP), including:

- IC file——Configuration files for client interfaces, including the interface layout settings, and the data, events, messages exchanged among application components,
- SC file——Configuration files for services registration, management, organization and business process definition,
- R file——Configuration files for relationships on information exchange, data sharing and network communication assurance among internal and external systems;
- LC file——Configuration files for equipment deployment and user management inside the system, and
- DC file——Configuration files for data access.

3）Submit these configuration files to the engine agent, which is in charge of assigning each file to the corresponding execution engine and controlling the execution order,

4）Each execution engine executes following its configuration file, so that the system is constructed automatically. These engines include:

- Interface Generation Engine(IGE)——Automatic generation of the client software according to the interface configuration files, and presentation of various data used in displaying, business processes, and requisitions,
- Process Execution Engine (PEE) —— Execution of the control flow following the process definition file, and integration of the services according to the service configuration file, so as to realize auto-execution and effective management of business processes (commercial products such as WPS of IBM),
- System Configuration Service (SCS) – Accomplishment of the deployment and management of seats, servers and controlled units inside the system, and configuration of the information exchange relationships among internal and external systems, and
- Data Access Engine (DAE) -- Provision of uniform, transparent, consistent and immediate access to the heterogeneous data.

5）Monitor the status of plan execution by the monitor and management services provided by each execution engines.

5 Conclusions

In this paper, a way of self-forming reconstruction of C2 system in net-centric environment is explored to meet the requirement of the agile organization and dynamic construction of Command and Control Communities of Interest. More specifically, the categories of operational plans are extended, the concept of C2SSP is proposed with its descriptive model given, an example C2SSP planning tool is shown, with a dynamic reconfiguration mechanism (plan-driven mechanism) of C2COI developed, and finally, a closed loop mechanism focused on C2SSP is established. Further research will be focused on C2SSP evaluation and optimization.

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The acronyms used in this paper are listed below.

C2COI	Command and Control Communities Of Interest
C2SSP	C2COI System Support Plan
NCW	Network Centric Warfare
UO	Unit Organization
OPLAN	Operational Plan
SOA	Service-Oriented Architecture
DoDAF	DoD Architecture Framework
URL	Uniform Resource Locator
UI	User Interface