Towards A Novel Web Services Standard-supported CDN-P2P Loosely-coupled Hybrid and Management Model

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Abstract—**In recent years, some researchers have begun to focus on researching CDN-P2P-hybrid architecture, but most hybrid architectures belong to tightly-coupled hybrid model. Cloud computing era calls for a more open content service mode. In order to construct open service relationship, we propose one novel CDN-P2P loosely-coupled SLA negotiation model. CDN firstly needs to provide an open and standard-based agreement interface for the P2P and other applications to negotiate with it. Therefore, we use Web Services Agreement Specification (WS-Agreement) for establishing agreement between two CDN and P2P. This scheme also allows CDN easily integrated with other application. The loosely-coupled CDN-P2P-SLA establishment needs to link with SLA performance monitoring, we design WSDM based CDN-P2P loosely coupled SLA monitoring scheme. The prototype system experiments have proved the feasibility of this model and scheme. Finally, we conclude this paper and analyze the prospective research direction.**

Keywords-Web Services;CDN;P2P;CDN-P2P-Hybrid;WS-Agreement; WSDM

I. INTRODUCTION

In recent years, IP networks TeleVision (IPTV), large-size file downloading and high-definition video have become mainstream broadband streaming content delivery applications. High-bandwidth, high-traffic and high quality of service, inherent in these applications, have brought huge challenges to the current best-effort Internet. How to implement large-scale, low cost, QoS guaranteed content delivery technology has become one core problem. In current content service platforms, CDN is a representative technique. Content Delivery Networks (CDN) is based on a large-scale distributed cache servers located closer to the edges of the Internet for efficient delivery of digital content including various forms of multimedia content. Now there are many commercial CDN companies, including Akamai, AT&T, NTT Communication, Limelight, Mirror Image, Level 3, Verisign and Internap.

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Although CDN is an effective means of streaming content access and delivery, there are two barriers to making CDN a more common service: expensive build cost and administration complexity. Deploying a CDN for publicly available content is very expensive. It requires administrative control over cache nodes with large storage capacity at geographically dispersed locations with adequate connectivity. Failed hardware components must be reported as well as failed or corrupted data replication. CDN can be scalable, but due to this administrative overhead and expensive cost, not rapidly expandable. With the emergence of Cloud Computing technology and development, it is a new trend that CDN needs to be more open and take on-demand service delivery model. Mukaddim Pathan et al. [2] propose that a Content Delivery Cloud extends the traditional CDN model. It makes use of “Cloud Computing", a recent technology trend that moves computing and data away from desktop and portable PCs into computational resources such as large Data Centers and make them accessible as scalable, on-demand services over a network (the “Cloud”). The main technical underpinnings of Cloud Computing infrastructures and services include virtualization, service-orientation, elasticity, multi-tenancy, power efficiency, and economics of scale [2]. Amazon recently stated they start offering an open content delivery network service as part of their S3 (Simple Storage Service) offering [3] and Microsoft reportedly creating their own CDN in open partnership with Limelight’s CDN. During 2009, the biggest CDN provider-Akamai’s CEO Paul Sagan might have signaled a shift in describing the company as a cloud computing provider, moving away from dreaded term "CDN"[1].

The emergence and maturity of Peer to Peer (P2P) streaming has been shown to greatly reduce the content delivery dependence on CDN, as well as bypass bottlenecks between content providers and consumers. Many research works have been taken in P2P live streaming and P2P VoD streaming [4]. There have been several large-scale P2P streaming applications to serve million of users, such as PPLive, Joost, PPStream, SopCast, et al. Indeed, streaming media content delivery using various peer-to-peer or peer-assisted frameworks allows the sharing of client resources, such as CPU, memory, storage, bandwidth, etc, and has greatly reduced the dependence on central content servers or CDN servers. P2P approach is more scalable and needs less

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investment. However, it has also fundamentally altered the relationship among content owners, network providers (ISPs) and consumers. Popularity of P2P streaming applications has resulted in increased traffic on ISP networks. P2P application is not easy to manage and the OoS is also a problem due to dynamic peer churn. Peers usually perform selfishly and they only care theirs own benefit and will ignore the global benefit, for example the back-bone consumption etc.

For the benefits of backbone network carries and ISPs, it is desirable that combining the features of P2P and CDN system, will best protect the previous investment and improve the service capability at the same time. A natural question is whether they can be combined to obtain the scalability advantage of P2P, as well as the reliability and manageability advantages of CDN. Indeed, with recent rapid growth of P2P applications and CDNs, many industrial and academic initiatives have been taken to combine the two technologies to get the "best of both worlds". One most challenging problem of current contents delivery network is to realize controllable, manageable, credible, network-friendly content distribution architecture through integration CDN and P2P.

In recent years, some researchers have begun to focus on CDN-P2P-hybrid architecture (e.g., [6-8] [12-18]). Cloud computing era calls for a more open content service mode, which requires content services available on-demand and be utilized in an open and loosely-coupled fashion. Although the research community has put many efforts on CDN-P2P-hybrid technology, most hybrid architectures belong to tightly-coupled hybrid model. To the best of our knowledge, loosely-coupled hybrid model is less explored. In this paper, we firstly focus on CDN–P2P-hybrid model analysis, and we compare two kinds of CDN-P2P hybrid model: tightly-coupled hybrid 1-to-1 model and loosely-coupled 1-to-N hybrid model. After that our paper makes the following main contributions:

1) In order to construct open service relationship, we propose one novel CDN-P2P loosely-coupled SLA negotiation model. Negotiable SLA management model needs CDN to provide an open and standard-based agreement interface for the P2P and other applications to negotiate with it. Therefore, we use Web Services Agreement Specification (WS-Agreement) to construct interfaces for establishing agreement between two parties; CDN and P2P can dynamically establish and manage agreements via WS-Agreement.

2) The loosely-coupled CDN-P2P-SLA establishment needs to link with SLA performance monitoring, we design WSDM based CDN-P2P loosely coupled SLA monitoring management scheme.

3) We integrate WS-Agreement and WSDM's open source project to realize Web Services standard-supported CDN-P2P Loosely-coupled VoD prototype system to verify the efficiency and feasibility of our scheme.

The remainder of this paper is organized as follows. We present related work is in Se. 2. In Sec. 3, we compare tightly-coupled hybrid model with loosely-coupled hybrid model. In Sec. 4, we explore and describe CDN-P2P loosely-coupled SLA negotiation model. In Sec 5, we design WS-Agreement based CDN-P2P loosely coupled SLA negotiation scheme. In Sec.6, we design WSDM based CDN-P2P loosely coupled SLA monitoring scheme. Section 7 describes our implementation scheme and experimental results. Finally, conclusions are drawn in Section 8 along with an outlook of future work.

II. RELATED WORK

Web Services technology has been verified to well support enterprise application integration (EAI) and B2B integration (B2Bi) solution. Ingo Brunkhorst et al. [9] point out those current applications in the multimedia domain cannot yet benefit from Web service architectures. They introduced a design of a semantic Web service framework for multimedia content adaptation. They specifically presented the workflow creation, service selection and validation for building large scale multimedia systems. Sascha Tonnies et al. [10] discussed the extensions of Web service frameworks, and presented a first implementation of a service-oriented framework for media streaming and digital item adaptation, concentrating on the technical realization of the services. Chen Wang et al. [11] presented an accountability service model, which makes important interactions between a service consumer and a service provider accountable. The model is based on the contract attached to the service interface definition. Differing from the related work above, our work focuses on constructing CDN-P2P loosely-coupled hybrid and management model based on multiple Web Services standards, including WS-Agreement and WSDM, WSRF, et al. This model can promote CDN become a more open infrastructure service in cloud computing era.

III. CDN–P2P-HYBRID MODEL ANALYSIS AND COMPARISON

CDN and P2P are two mainstream content delivery technologies in the current Internet, but constrained by the computing model, both of them have their own advantages and some fundamental shortcomings. The two models have greater complementarities, so their integration is an important trend. We need to research CDN and P2P hybrid delivery model for realizing controllable, manageable, credible, network-friendly content distribution technology. We summarize there are two kinds of CDN-P2P hybrid model: tightly-coupled hybrid model vs loosely-coupled hybrid model.

A. Tightly-coupled hybrid 1-to-1 model

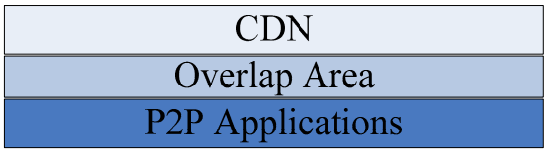

Figure 1. Tightly-coupled hybrid 1-to-1 model

The tightly-coupled hybrid model is 1-to-1 model. It means one CDN system can only integrate with one P2P system. As shown in Figure 1, CDN and P2P have overlap area, where CDN nodes and P2P nodes closely collaborate to execute content delivery function, for instance, the CDN

nodes act as sub-tracker to involve in construction process of P2P overlay network; CDN nodes manage and guide P2P nodes to realize ISP-friendly P2P delivery, CDN nodes and the P2P nodes collaborate on content delivery. Our PeerCDN [7] is one kind of typical 1-to-1 tightly-coupled hybrid model. PeerCDN realizes the management of regional autonomy when constructing overlay network. The overlay network is constructed geographically to become topology-aware overlay network through redirecting of strong nodes. In our PeerCDN architecture, each group of client peers is led by the nearest strong node from CDN.

In this model, P2P system is attached to the CDN system. In other words, CDN nodes lead to build P2P systems. This model is efficient for one CDN integrating with only one P2P system, but it is not suitable for one CDN integrating with multiple P2P. For example, PPLive and PPStream are two largest P2P streaming media companies in China. If PPLive and PPStream want to integrate with CDN through such method, PPLive and PPStream have to break their current overlay construction and data transmission mechanism to adapt to CDN, which will increase the integrating difficulty.

B. Loosely-coupled hybrid 1-to-N model

It is a prerequisite for new generation CDN that content services are available on-demand and that they are utilized in an open and loosely coupled fashion. Therefore, if a CDN operator wants to integrate with a number of heterogeneous P2P and other application operators, it needs to expose public service interface to serve multiple P2P operators, including the redirection service interface, data service interface, service negotiation interface, and other interfaces. This integration method belongs to one kind of loosely-coupled 1-to-N hybrid model. Just as shown in Figure 2, Loosely-coupled hybrid model refers that CDN can provide services for multiple P2P systems or other applications with public service interfaces, rather than tightly integrated with only one P2P system. CDN is not directly involved in the construction of P2P overlay network, and CDN does not directly lead P2P systems, but when one P2P system builds its overlay network, it can make use of redirection service interface of a wide range deployed CDN nodes, to realize the friendliness to ISP, and to find the nearest neighbor in the same CDN region. At the same time, P2P nodes can also request contents from the CDN nodes data transmission service interface when needed, such as an emergency or flash crowd happens.

For example, China Telecom, as Chinese largest network operators, are building a large-scale CDN system, they want to make their CDN to provide services for more P2P streaming operators (PPLive, PPStream, UUSee et al.), video website, online game operators, and other application operators in parallel, such as content accelerating services. Therefore, they require such kind of loosely-coupled 1-to-N hybrid model.

Web Services interfaces are neutral for platform and technology, so application business objects can integrate easily through Web Services. In order to improve our PeerCDN architecture, we proposed WS-CDSP [8]: a novel Web Services-based Content Delivery Service Peering Scheme, which can support loosely-coupled multimedia content peering delivery service architecture. WS-CDSP belongs to such loosely-coupled 1-to-N hybrid model. The main function is to enable explicit cooperation and integration among P2P, CDN and VoD.

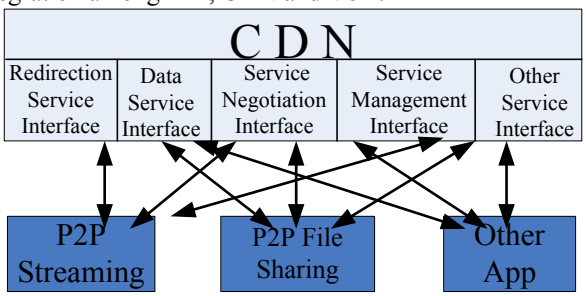

Figure 2. Loosely-coupled hybrid 1-to-N model

In WS-CDSP, in order to support explicit cooperation between P2P, CDN and VoD, every P2P, CDN and VoD system is added two endpoints: one is Web Service Information Endpoint; the other is Web Service Management Endpoint [8]. Web Service Information Endpoint can act as black box interface to expose the system information of CDN, VoD, or P2P. CDN and VoD system can provide cache or VoD server node information, topology structure information, and media content item information through Web Service Information Endpoint and all these information can be described with XML and exposed by WSDL [8]. Web Service Management Endpoint provides manageable interface, and platform manager can monitor the running load status of CDN ,VoD, or P2P, or subscribe the events [8]. CDN and P2P can be loosely integrated through these interfaces.

IV. CDN-P2P LOOSELY-COUPLED SLA NEGOTIATION MODEL

In recent years, cloud computing has allowed the virtualization provisioning of infrastructure resources as well-defined discrete services. Such offerings are referred to as Software as a Service, Infrastructure as a Service, Platform as a Service, or Storage as a Service, et al.

Therefore, we see the emergence of a vivid service economy, where business customers can purchase high level business service bundles, relying on software services and on virtual infrastructure/platform services [19]. The establishment of the business relationships and the business/software/infrastructure service chains required contracts. Service Level Agreements (SLA) are the instruments to model such contracts in the digital world, since they specify the conditions under which a certain service is provided by a provider to a customer.

Therefore, P2P and CDN need some negotiable service configuration and guarantee management capabilities. Negotiable management capabilities are CDN and P2P need to negotiate to make Service Level Agreements (SLA) so as to build a guaranteed service relationship. An agreement between a P2P application and a CDN service provider specifies one or more service level objectives (SLO) both as expressions of requirements of the P2P application and

assurances by the CDN service provider on the availability of resources and/or on service qualities. For example, an agreement may provide assurances on the bounds of CDN service startup time, content chunk size, and available bandwidth speed for every content chunk transmission session.

In order to construct this kind of service relationship, we propose CDN-P2P Loosely-coupled SLA Negotiation Model, as shown in Figure 3, and the following describes the main interaction process between P2P service consumer and CDN service provider in this model.

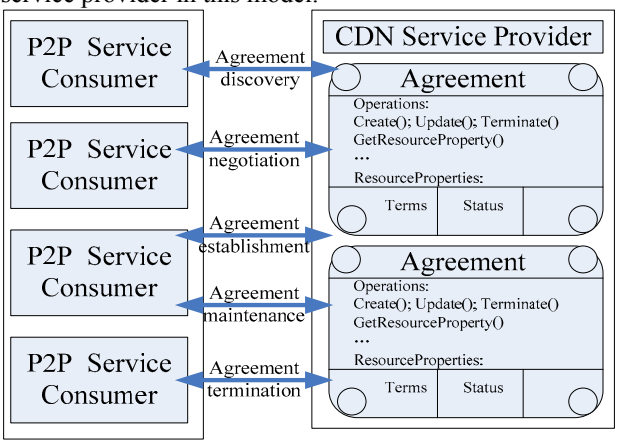

Figure 3. CDN-P2P Loosely-coupled SLA negotiation model

- Agreement discovery: A P2P system needs to find a series of acceptable agreements from any CDN service it want to reach an agreement with. This provides a base interface on which to build a new agreement.
- Agreement negotiation: The lifecycle of a single SLA starts with its negotiation. In this phase, P2P system sends an agreement proposal to CDN party. When the CDN party receives the proposal from P2P party, the CDN can respond to those requests with acceptance or rejection.
- Agreement establishment and running: An agreement between P2P and a CDN is built to specify one or more service level parameters, such as service response time, delivery chunk size, I/O speed, and available bandwidth speed. CDN will follow the agreement to provide run-time services for P2P.
- Agreement maintenance and updating: The process to renegotiate an existing agreement between P2P and a CDN and the ability to notify /accept notifications from another party that an agreement term has been broken, effecting the state of an agreement and possibly resulting in the updating of some agreement items in response.
- Agreement termination: The process to quit and terminate an agreement and notify the other party.

V. WS-AGREEMENT BASED CDN-P2P LOOSELY COUPLED SLA NEGOTIATION SCHEME

In order to provide an open service interface, CDN firstly needs to provide an open and standard-based agreement interface for the P2P and other applications to negotiate with it. CDN and P2P can dynamically establish and manage agreements via Web service interfaces. Therefore, we select Web Services Agreement Specification (WS-Agreement) [20] as agreement interaction protocol. WS-Agreement is a Web Services standard of the Open Grid Forum (OGF) for establishing agreement between two parties, such as between a service provider and consumer, using an extensible XML language for specifying the nature of the agreement, and agreement templates to facilitate discovery of compatible agreement parties [20]. The specification consists of three parts which may be used in a composable manner: a schema for specifying an agreement, a schema for specifying an agreement template, and a set of port types and operations for managing agreement life-cycle, including creation, expiration, and monitoring of agreement states [20].

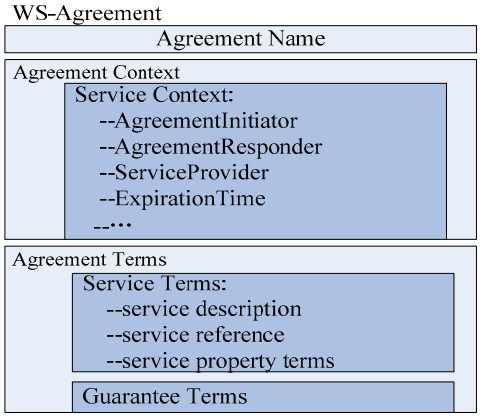

Figure 4. Structure of WS-Agreement

An agreement is conceptually composed of several distinct parts. We summarize the structure in Figure 4: The section after the agreement name is the agreement context, which contains the meta-data for the entire agreement. It names the participants (Agreement Initiator, Agreement Responder, and Service Provider) in the agreement, and the agreement's Expiration Time, et al.

The Agreement terms provide information needed to instantiate or otherwise identify a service to which this agreement pertains and to which guarantee terms can apply. These are further refined as service description, service reference and service property terms. The guarantee terms specify the service levels that the parties are agreeing to. Management systems may monitor the service and enforce the agreement according to the guarantee terms. The Figure 5 illustrates a basic CDN-P2P loosely-coupled agreement sample. In this sample, The Agreement Terms consist of the ServiceDescriptionTerm and the GuaranteeTerm. The ServiceDescriptionTerm includes "TotalBandwidthCapacityForEachP2P", "SizeOfContentChunk", and "BandwidthSpeedPerLink". The TotalBandwidthCapacityForEachP2P means the negotiated CDN's total distribution bandwidth capacity for every P2P application, for example, one agreement term is 30Mbps, and another agreement term is 40Mbps. The SizeOfContentChunk means the negotiated content chunk size for every time's distribution from CDN to P2P, such as 30KB, 40KB and so on. The BandwidthSpeedPerLink means

the negotiated speed for every connection's distribution from CDN to P2P, such as 300Kbps, 500Kbps, et al. Correspondingly, the GuaranteeTerm includes TotalBandwidthCapacityForEachP2P,SizeOfContentChunk, and BandwidthSpeedPerLink.

```
<?xml version="1.0" encoding="UTF-8"?>
<wsag:AgreementOffer
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:wsag="http://schemas.ggf.org/graap/2007/03/ws-agreement"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
xsi:schemaLocation="http http://schemas.ggf.org/graap/2007/03/
wsagreement
agreement_types.xsd http://www.w3.org/2001/XMLSchema
XMLSchema.xsd http://www.gridforum.org/namespaces/job job_terms.xsd
http://foo.org/sdtc SDTCondition.xsd"
wsag:AgreementId="CDN-P2P Integration Sample">
<wsag:Name> CDN-P2P Integration Agreement 1</wsag:Name>
<wsag:Context/>
<wsag:All>
  <wsag:Terms>
    <wsag:ServiceDescriptionTerm
        wsag:Name="TotalBandwidthCapacityForEachP2P"
        wsag:ServiceName="CDN.Shanghai.ChinaTelecom">
        <job: SizeOfContentBlock >20Mbps</job: SizeOfContentBlock >
    </wsag:ServiceDescriptionTerm>
    <wsag:ServiceDescriptionTerm
        wsag:Name="SizeOfContentChunk"
        wsag:ServiceName="CDN.Shanghai.ChinaTelecom">
        <job: SizeOfContentBlock >100KB</job: SizeOfContentBlock >
    </wsag:ServiceDescriptionTerm>
    <wsag:ServiceDescriptionTerm
        wsag:Name="BandwidthSpeedPerLink"
        wsag:ServiceName=" CDN.Shanghai.ChinaTelecom ">
        <job: BandwidthPerLink >300Kbps</job: BandwidthPerLink >
    </wsag:ServiceDescriptionTerm>
    <wsag:GuaranteeTerm wsag:Name="ConfigurationPreference"
        wsag:Obligated="ServiceProvider">
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<wsag:ServiceName> CDN.Shanghai.ChinaTelecom   </wsag:ServiceName>
        </wsag:ServiceScope>
          <wsag:ServiceLevelObjective xsi:type="sdtc:OpType">
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              <SDT> TotalBandwidthCapacityForEachP2P</SDT>
              <SDT> SizeOfContentChunk </SDT>
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          </Or>
          </wsag:ServiceLevelObjective>
     </wsag:GuaranteeTerm>
 </wsag:Terms>
 </wsag:All> </wsag:AgreementOffer>
```

Figure 5. CDN-P2P loosely-coupled agreement sample

VI. WSDM BASED CDN-P2P LOOSELY COUPLED SLA MONITORING SCHEME

The agreement defines a dynamically-established and dynamically-managed relationship between CDN and P2P. The object of this relationship is the content delivery service from CDN to P2P within the context of the agreement. The management of content delivery is achieved by agreeing on the respective roles, rights and obligations of the parties. The agreement may specify not only functional properties for identification or creation of the service, but also non-functional properties of the service such as performance or availability. In a distributed service-oriented computing environment, service consumers like to obtain guarantees related to services they use, often related to quality of a service. Whether service providers can offer and meet guarantees usually depends on their resource situation at the requested time of service. Hence, quality of service and other guarantees that depend on actual resource usage cannot simply be advertised as an invariant property of a service and then bound to by a service consumer. Instead, the service consumer must obtain state-dependent guarantees from the service provider, represented as an agreement on the service and the associated guarantees. Additionally, the guarantees on service quality should be monitored and service consumers may be notified of failure to meet these guarantees [20].

Therefore, SLA management needs to link with SLA performance monitoring so that CDN-P2P-SLA establishment can guarantee CDN to serve the needs of P2P. SLA negotiation and monitoring involve both the service consumer (P2P) and CDN service provider, and we need decompose service level objectives into monitorable performance terms. Monitoring performance terms can collect SLA violations during the provisioning of a service under the terms of an SLA.

The loosely-coupled CDN-P2P hybrid open system needs a novel loosely-coupled service management environment. One CDN system can serve multiple P2P systems, while one P2P system also can loosely couple with multiple CDN systems. Therefore, CDN and P2P belong to different administrative domains. In this case, we can not adopt the tightly-coupled management approach. There may be situations where it is desirable for a P2P allied system outside a CDN management domain to have access to the management interface of CDN service. Traditional systems management protocols such as SNMP, JMX, WMI can not meet the requirements of cross-domain loose management.

The OASIS Web Services Distributed Management Technology Committee is defining a set of Web Services Distributed Management (WSDM) specifications [21]. The WSDM specifications define how to use Web services to expose manageable resources (MUWS), and in addition, define how to expose manageable Web service implementations (MOWS - this specification). Following the WSDM concepts, the manageability consumer discovers the manageability endpoint and exchanges messages with it in order to request information, subscribe to events or control the manageable endpoint resource.

Through exposing WSDM interface in CDN side, we can make P2P content consumer to remotely monitor the some SLA-related CDN performance within agreement. The main management interfaces are described as follows [21]:

TABLE 1. WSDM INTERFACE IN CDN RESOURCE SIDE

Interface Name & Description	Sample Use Case
The GetResourceProperty operation retrieves the value of a specified resource property for a manageable resource.	Using this interface, P2P can query one service status term from CDN, such as current BandwidthPerLink.
The GetMultipleResourceProperties operation retrieves values for a specified set of resource properties for a manageable resource.	Using this interface, P2P can query multiple service status terms once from CDN.
The QueryResourceProperties operation retrieves a portion of the resource properties document from a manageable resource using a query language such as XPath.	Using this interface, P2P can use XPath query language to more flexibly monitor agreement-related service status of CDN.
The SetResourceProperties operation takes resource properties	As P2P and CDN is a loosely coupled

as supplied by a manageability consumer and correspondingly modifies (inserts, updates, and/or deletes) the given properties in the resource property document for a manageable resource.	management relationship, therefore, in most cases, P2P has no right to change or update resource properties of CDN. Only a few cases can use this operation.
The Subscribe operation requests that notifications be sent to a manageability consumer. &The Notify operation receives notifications on behalf of a manageability consumer.	P2P can use this operation to subscribe event of CDN. When some events happen to meet the subscription conditions in CDN node, it will notify P2P system.
The GetCurrentMessage operation requests that a notification producer for a manageable resource return the last notification on a given topic.	P2P can get last notification on a given topic from CDN.
The PauseSubscription/ ResumeSubscription operation requests a temporary hold on an existing subscription for a manageability consumer.	Using this interface, P2P can pause/ resume Subscription on a given topic from CDN.

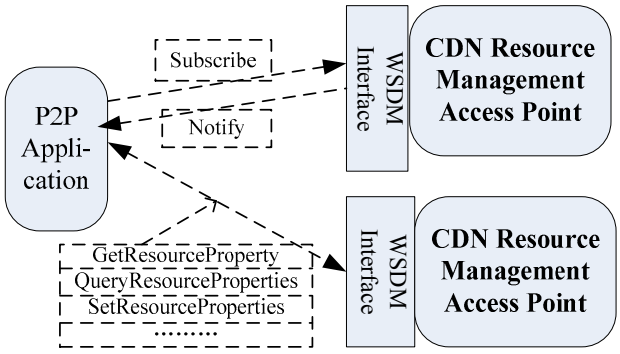

Figure 6. WSDM -based monitoring architecture

Just as shown in Figure 6, CDN provide multiple management interfaces to P2P application, including Subscribe, Notify, GetResourceProperty, GetMultipleResource Properties, SetResourceProperties, and so on.

Although CDN provide multiple management interfaces to P2P, sometimes the P2P allied system is not allowed the right to access some of these management interfaces or carry out some management operations. There should be the possibility of executing a customized operation, such as add a new management interface to the allied CDN entity within the CDN services administrative domain. Fortunately, WSDM provides a Manageability Capability as follows [22]: A manageability endpoint offering a new capability is free to ignore all standard manageability capabilities defined by MUWS except for the Identity capability.

Therefore, we can utilize WSDM customized manageability capabilities actions to implement the novel management interface to support the new management requirement of CDN-P2P loosely-coupled model.

VII. PROTOTYPE SYSTEM IMPLEMENTATION AND EXPERIMENTS ANALYSIS

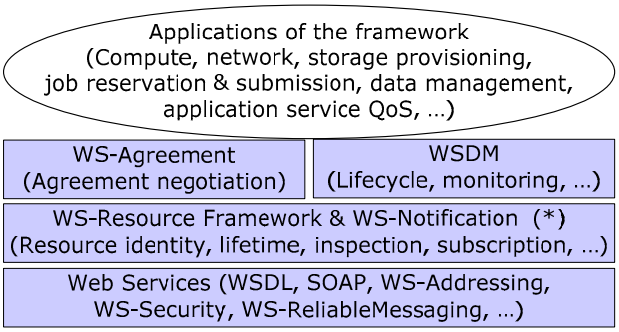

Figure 7. Web Services resource protocol stack

We use the Web Services resource protocol hierarchy architecture to implement our prototype system. As illustrated in Figure 7, both WS-Agreement and WSDM are dependent on some basic Web Services standards, including Web Services Resource Framework (WSRF) [26], WS-Notification, WSDL, SOAP, WS-Addressing, and so on. In particular, WSRF [24] comprise of WS-Resource, WS-ResourceProperties, WS-ResourceLifetime, WS-ServiceGroup and so on. WSRF protocol stack is common basis of WS-Agreement and WSDM.

We use MUSE and WSAG4J as main basic library to support the Web Services resource protocol hierarchy architecture above. MUSE [22] is a Java-based implementation of the WS-Resource Framework (WSRF) 1.2, WS-Base Notification (WSN) 1.3, and WS-Distributed Management (WSDM) 1.1 specifications. It is a framework upon which users can build web service interfaces for manageable resources without having to implement all of the "plumbing" described by the aforementioned standards. WS-Agreement for Java (WSAG4J) [23] is a generic implementation of the WS-Agreement protocol. It supports common functionality to create and monitor agreements in a generic way.

Our prototype system is developed based on the previous WS-CDSP [8] P2P VoD system. Just as shown in Figure 8, in the CDN-P2P-hybrid VoD delivery system, we have 4 servers, including 1 CDN service portal server, 1 CDN monitor server, 1 central server, and 1 CDN node server. At the same time, 400 clients act as peer node, and they share the cached content with each other. We have one P2P tracker server, which can guide peer node to find CDN node or other peer node.

We develop WS-Agreement interface based on WSAG4J library in the CDN service provider portal, at the same time, we develop WSDM interfaces based on MUSE in the same portal. WSAG4J brings its own WSRF stack based on the MUSE framework in order to release the developer from the burden of implementing the whole web service stack required by WS-Agreement specification [23]. Therefore, WSRF stack is common intersection of WS-Agreement and WSDM.

Figure 8 illustrates the interaction implementation between P2P application and CDN service provider in prototype system. If one P2P application wants to reach

alliance relationship with CDN, P2P application first needs to interact with open WS-Agreement interface of CDN portal. Here we use P2P tracker as P2P community requestor. P2P tracker firstly creates an agreement based on the agreement document template and submit it to the CDN service portal; and then the management component will evaluate the proposed agreement and query its current resources usage from CDN Server Node Monitor, and then make the consent or refuse decision; Finally, if agree, the assigned agreement will contain service terms and guarantee terms. In particular, WS-ResourceProperties and WS-ResourceLifetime are used to represent Agreements as WS-Resource. And then the CDN provider will create a static WS-Resource, the proposed agreement terms will be transformed into WS-ResourceProperties.

Just as describe above, WSDM is also dependent on WS-ResourceProperties, and WS-ResourceLifetime. Therefore, WS-Resource is the intersection and bridge of WS-Agreement and WSDM, as Figure 8 illustrating. WSDM management component will update the WS-Resource through adding monitored terms based on agreed terms. Therefore, the execution of the agreed terms can be monitored by corresponding monitored terms. When P2P tracker accesses to WSDM interface, it can monitor the same WS-Resources created by WS-Agreement. For example, if one agreed term is CDN node bandwidth service capacity, then monitored term is CDN node real service throughout. When P2P tracker access WSDM interface "GetResourceProperty", WSDM management component will retrieve CDN node real service throughout from CDN specific server node monitor and return resource properties to P2P tracker.

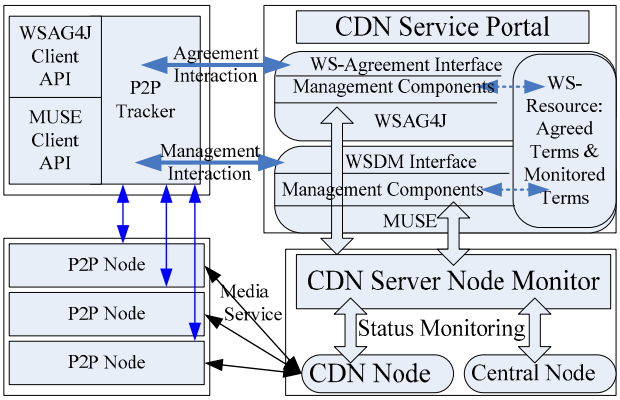

Figure 8. Prototype system implementation architecture

From the users experience's point of view, a good QoS of P2P VoD streaming requires a fast startup time. A fast startup time would be possible if user can receive a few of continuous chunk at the forefront of the media content in around 15-17 seconds. The chunk size can also affect the speed and success rate of fetching chunks. In our VoD experiment, P2P node will obtain front continuous chunks from the CDN to startup playing. Before fetching startup chunks, P2P tracker will negotiate with the CDN about startup chunk size "SizeOfContentChunk" and "BandwidthSpeedPerLink": distribution bandwidth speed for these chunks. Here P2P tracker firstly negotiates 30KB chunk sizes with CDN and then updating the agreement terms to 60KB, 90KB, 120KB. In every agreement, we use one CDN node send different size chunk with the same 300Kbps BandwidthSpeedPerLink and the TotalBandwidthCapacityForEachP2P is 60Mpbs. The peer playing speed is 300Kbps.

We get the experiment results as Figure 9 illustrated. When the peer node number of concurrent accessing CDN node is less than 200, the chunk size is the greater and the start-up time is shorter. We can observe, when the parallel peer nodes is around 40, startup time is respectively 5 seconds, 6 seconds, 10 seconds, and 16 seconds around when corresponding chunk size is 120KB, 90KB, 60KB, and 30KB. When the peer node number of concurrent accessing CDN node is more than 200 and the CDN node become overloaded, the situation is beginning to reverse. As the smaller the chunk size is, the shorter the startup time is. When the parallel peer nodes is 250 around, the P2P tracker get WSDM overload notification from the CDN node. The greater the chunk size is, the sooner the overloaded notification is produced. We analyze the reason is that: when CDN node began to be overloaded, a larger chunk distribution will cause greater distribution pressure on CDN server node. Therefore, the larger size distribution is not always good.

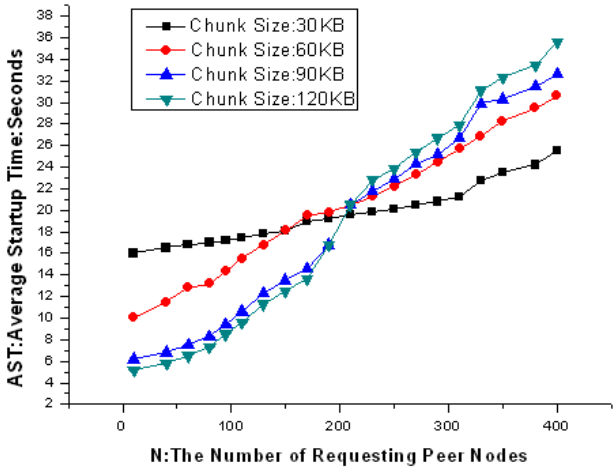

Figure 9. Average startup time with different chunk

At the same time, in an emergency, P2P nodes can also request content chunks from the CDN nodes. Therefore, P2P tracker will also negotiate with the CDN about emergency chunk size and distribution bandwidth capacity for these chunks in advance. Here P2P tracker firstly negotiates "TotalBandwidthCapacityForEachP2P": 10Mbps bandwidth capacity with CDN, and then respectively updating Agreement terms to 20Mbps, 30Mbps, 40Mbps, and 60Mbps, and in every connection, CDN node send the same size chunk with 60KB every time. The Figure 10 evaluates the influence of negotiating different bandwidth capacities on P2P emergency handling situation. We can observe: when more peer nodes request content from CDN, if the negotiated bandwidth capacity is smaller, the failure probability is larger. The reason is that the CDN bandwidth capacity is proportional with its service capability. Greater service capacity can handle more peer nodes' emergency situations.

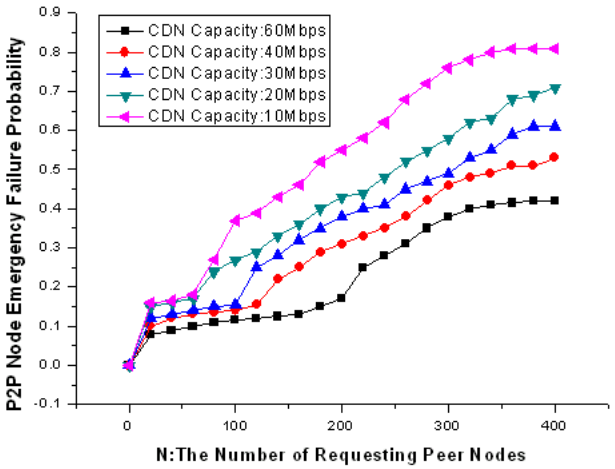

Figure 10. P2P node emergency failure probability with different CDN service capacity

VIII. CONCLUSION AND FUTURE WORK

Just as above described, CDN and P2P are two mainstream content delivery technologies in the current Internet, but constrained by the computing model, both of them have their own advantages and fundamental shortcomings. The two techniques have greater complementarities, so their integration is very necessary and helpful to build new-generation manageable, high-QoS, and large-scale content service system. However, this integration is not simple to complete. A common content distribution platform is not a simple superposition of CDN and P2P, integration of CDN and P2P need to solve many problems. Specifically, the integration of CDN and P2P needs more open and loosely-coupled mode. Web Services are a set of standards and technologies to integrate applications within the enterprise and also enable standards based integration with partner applications. In this paper, we propose one novel Web Services standard-supported CDN-P2P Loosely-coupled hybrid and management model. And we design WS-Agreement based CDN-P2P loosely coupled SLA negotiation scheme and WSDM based CDN-P2P loosely coupled SLA monitoring management scheme.

In order to establish new-generation content delivery solution, reliable, secure and friendly hybrid delivery models need to be researched in depth. In our future work, we will focus on designing more Web Services standard-supported loosely-coupled hybrid models, and developing more prototype systems to experimentally verify the advanced features of these models and related algorithms. Finally, we plan to carry out larger scale experiments with our prototype and make real deployment in our ongoing CNGI (China Next Generation Internet) project- National Higher Education Conference Video Resources Sharing Project.

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