明新科技大學　校內專題研究計畫成果報告

點對點同儕網路與網路拓墣架構一致性之研究
Improving Topology Consistent Mapping between Peer-to-Peer Overlay Network and Underlying Network Topology

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中文摘要

近年來，同儕網路已經成為一個流行的網路架構，主要應用於文件與檔案的分享。而且同儕網路有許多的特色，例如沒有中央的伺服器而且各端點都是平等。此外也有商業的產品，例如 Skype，實現了同儕網路的應用。但是這樣的架構卻存在著不一致性的問題，主要是因為同儕網路是一個邏輯連結的虛擬網路架構，並沒有考慮到實際網路拓墣之間的關係，這會導致邏輯上的連結雖然很接近，但是實際的網路拓墣的距離卻很遠離，這會產生網路效率不佳的狀況。然而傳統的方法皆使用網路延遲來決定節點間的距離，進而利用這些資訊來改善，本計劃則提出另一個看法，利用網路拓墣間的連結資訊作為改善同儕結構的因子，進而改善整個同儕網路的連結使同儕網路的整體效率提升。另外，我們也提出一個智慧型家庭網路的應用，並利用本計劃所提出的方法使智慧型家庭網路實用化，並改善家庭網路中異質性網路連結的問題。

關鍵字：點對點網路、同儕網路、網路拓墣、家庭網路、通用即插即用

英文摘要

In recent years, Peer-to-Peer overlay network is a popular medium especially for documents or files sharing and have many features including no central server and peers are equal. But there exists a mis-match problem between peer-to-peer overlay network and physical network topology. Because when the files are transmitted between peers that are closed in peer-to-peer overlay network, the physical network location of the peers are not closed. This results inefficient transmission or routing between peers in the peer-to-peer overlay network. On the other hand, the situation will have serious delay in real-time service, for example streaming service. Therefore, our work proposes a mechanism based on physical network hop information and situation that is different from traditional approach that using network delay information as the information to construct the peer-to-peer overlay network and adjust the arrangement of peer-to-peer overlay network dynamically. On the other hand, we also design a middleware implementation of intelligent home network environment to make our proposed mechanism in practical. By using peer-to-peer overlay network, we also solve the heterogeneous network topology in intelligent home network environment design.

Keyword : peer-to-peer overlay network, network topology, home network, UPnP

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1. INTRODUCTION

In recent year peer-to-peer overlay network have been became a popular application model to provide several applications including file-sharing, load balance etc.. Peer-to-peer overlay network is a distributed and virtual architecture without considering underlying network topology. Gnutella, Freenet, Naspter, CAN, Chord, Pastry, Tapestry are the famous peer-to-peer overlay network architecture to realize these usage. Because the hosts in the peer-to-peer overlay network are connected in a virtual way, the data transferring do not consider the efficient usage of underlying network topology. When a host transmits a data to another host, the transmission path will be according to overlay network topology. Therefore, the nearby host in peer-to-peer overlay network might have long distance in the underlying network so that the efficiency of transferring might be in worse situation. This problem is called mismatch problem in peer-to-peer overlay network. Now we can consider the overlay network and underlying network topology relationship in Figure 1. When host A transfer a data piece to host B according to the overlay network topology in Figure 1. The actual data transferring path is A→C→D→B according to the underlying network in Figure 1. The actual transmission path is not reflected with the better topology in overlay network. We can consider another scenario according to the Figure 1. When host A send a data piece to host D, the data will be transferred from host A to host D via host B. But the actual transmission path will be A→C→D→B→D, the path between host B and host D are visited twice and cause the redundant messages to degrade the network performance and overall throughput.

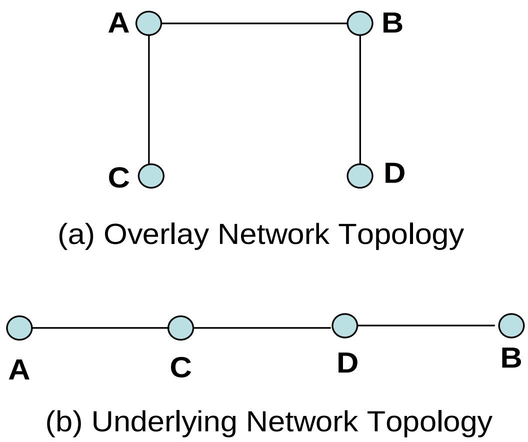


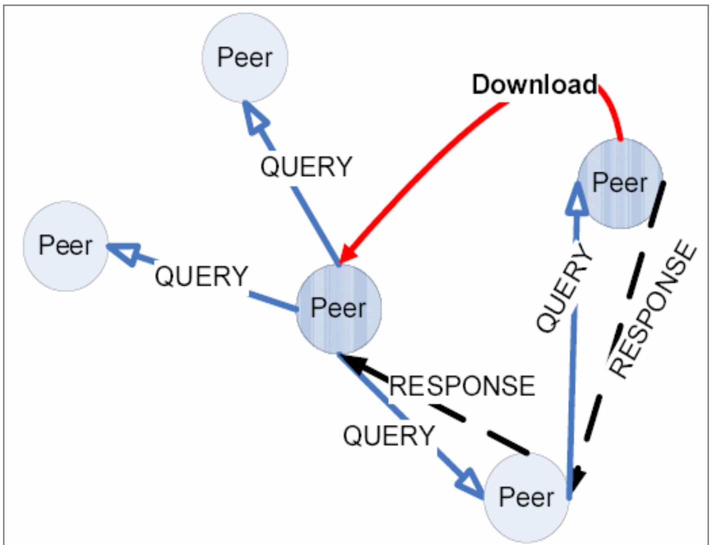
Figure 1 : Overlay Network and Underlying Network Topology

Therefore, in this research we focus on the investigation of the mismatch problem and consider the solution to resolve. On the other hand, we also apply this result to establish an intelligent home network environment over peer-to-peer overlay network.

2. RELATED WORK

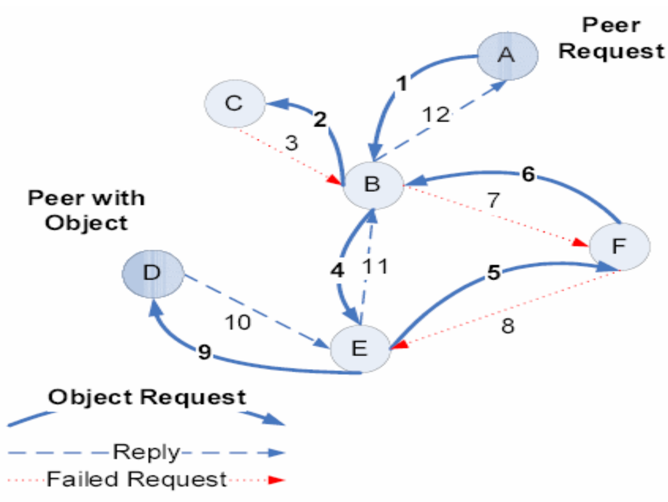
In this section, we will investigation the literatures related with the peer-to-peer overlay network and mismatch problem in overlay network.

In general, peer-to-peer overlay network can be divided into two basic categories including unstructured peer-to-peer overlay network and structured peer-to-peer overlay network. The famous unstructured peer-to-peer overlay network includes Gnutella[6], FreeNet[7], Fasttrack/KaZaA[9], BitTorrent[10] etc.. The hosts in these overlay network are connected in a random and distributed way. In order to query the data pieces in overlay network, these overlay network use flooding, random walks or expanding-rich TTL approaches to query data pieces. Figure 2 and Figure 3 shows the search example with respect to Gnutella[6] and Freenet[7]. The query message is sent to other peers to search the needed data pieces and the query message is also forwarded by these intermediate hosts to enhance the query scope. But the problem that message will be sent and reply in a long period will be produced. Therefore, another architecture Fasttrack/KaZaA[10] is proposed to enhance the query performance. In this architecture, a super node is proposed to index the data pieces and the nodes hold the data pieces belong to the super node. The hosts in overlay network are organized as the hierarchy architecture. Figure 4 shows the example of Fasttrack[8].



Gnutella utilizes a decentralized architecture document location and retrieval.

Figure 2 : An Example of Query Message in Gnutella[6]



A typical request sequence in Freenet.

Figure 3 : An Example of Query Message in Freenet[7]

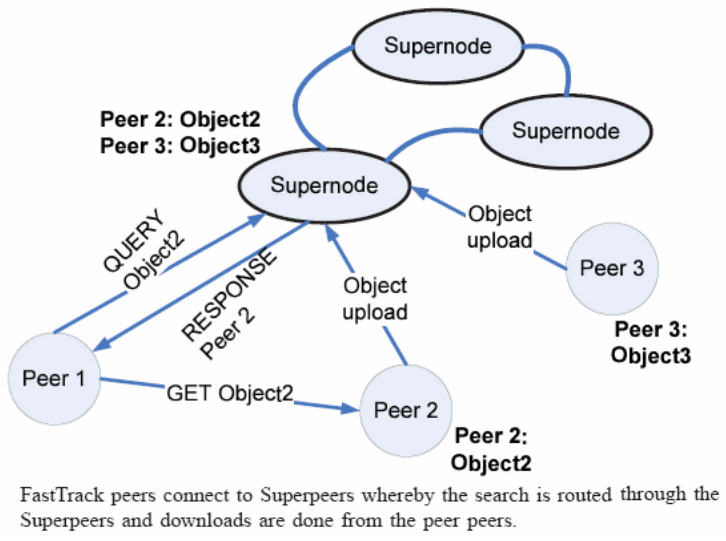


Figure 4 : An Example of Fasttrack[8]

Another kind of peer-to-peer overlay network is structured peer-to-peer overlay network. The famous are CAN[1], Chord[2], Pastry[3] and Tapestry[4]. These architectures are based on Distributed Hash Table(DHT) mechanism to allocate the hosts in the overlay network. DHT assign *key* to the data and compute a *value* for the *key*. The *(key, value)* pair is used for retrieving and locating the data item on a peer. CAN[1] is the first architecture of peer-to-peer overlay network. The hosts are located in a geographic way. The overall hosts' spaces are divided into d-dimension Cartesian coordinated spaces. Each host in overlay network belongs to on a distinct zone in the overlay network. Figure 5 shows the example of the CAN[1].

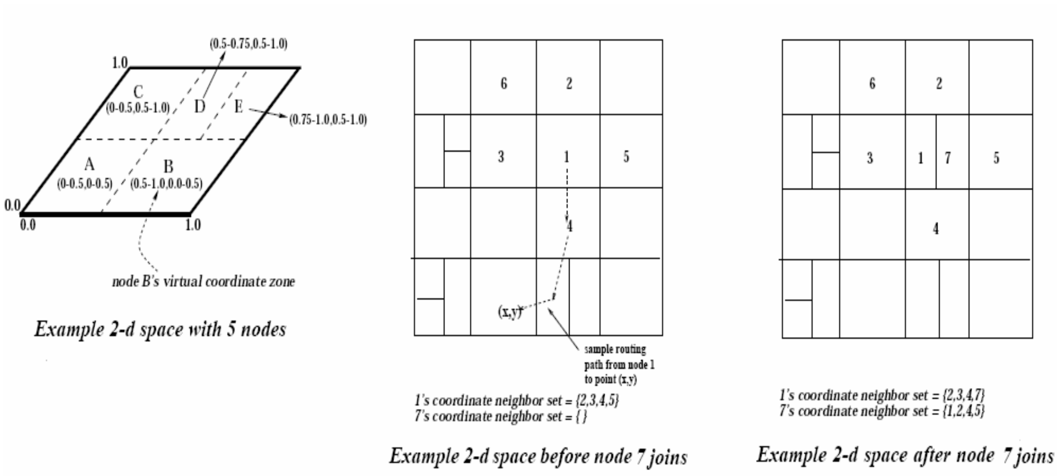
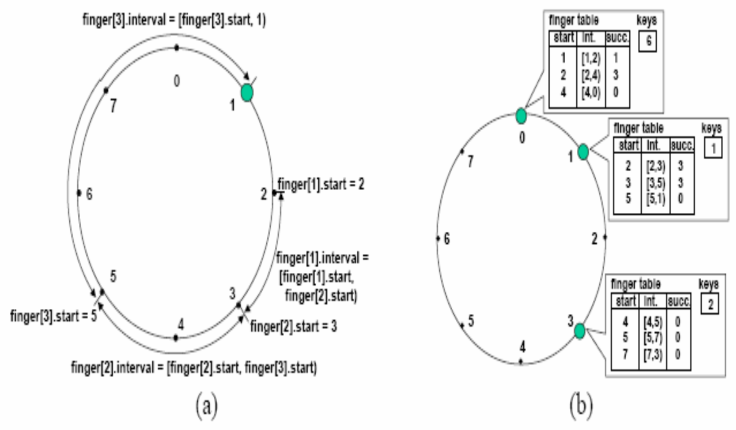


Figure 5 : An Example of CAN[1]

Chord[2] is another famous structured peer-to-peer overlay network. Chord[2] organizes the hosts in a ring structure. Each host maintains a finger table as the routing table and the routing path will be according to the finger table. The query message will be transmitted in a clockwise way until the data piece is found or not. Figure 6 shows the example of the Chord[2].



(a) The finger intervals associated with node 1. (b) Finger tables and key locations for a net with nodes 0, 1, and 3, and keys 1, 2, and 6.

Figure 6 : An Example of Chord[2]

The above peer-to-peer overlay networks all have mismatch problem because they do not consider the underlying network topology in constructing the overlay network. Liu *et al.* propose several solutions to resolve the mismatch problem for unstructured pee-to-peer overlay network. In 2004, Liu *et al.*[12] propose a location-ware topology matching(LTM) technique to solve mismatch problem in unstructured peer-to-peer overlay network. In LTM host does not require global topology of peer-to-peer overlay network to optimize the overlay network structure. LTM issue a detector to detect the delay information in a constrained range(hops) and hosts collect these information to estimate the optimized overlay network structure. At the same time, Liu *et al.*[13] also propose another mechanism Adaptive Connection Establishment(ACE) algorithm to resolve the mismatch problem. Hosts collect the delay information by send the probing message and then calculate the minimum spanning tree as the optimized overlay structure according to the collecting delay information. Based on the optimized overlay structure, the host will probe other hosts to find the other closed host and try to establish overlay connection with the better host. Another mechanism scalable bipartite overlay scheme(SBO) is proposed by Liu *et al.*[31] to resolve the mismatch problem and that is similar with the ACE algorithm. But SBO divide the hosts into two types, one is responsible for collecting delay information and the other is responsible for calculate the optimized overlay structure. Therefore, overall performance of algorithm of finding optimized overlay network is improved.

Xin Yan Zhang *et al.*[22] propsoe mOverlay to resolve mismatch problem also. They take the locality of the hosts, i.e. distance, into account to construct the overlay network by using dynamic landmark. They introduce the group concept that hosts in group have same distance with group's neighbors. The group's neighbors are the dynamic landmark node to find the minimum distance.

Tongqing Qiu *et al.*[23] propose a generic approach to construct the topology-aware overlay network and they also use landmark as the basic scheme. By using the information from the landmark, the two hosts will be swapped to have better performance in overlay network. The decision for swapping is based on the calculation of delay information before swapping and after swapping. If the performance before swapping is better than after swapping, the two hosts will not swap to exchange hosts' information. Otherwise, they swapped to have better overlay network topology.

Guangtao Xue *et al.*[24] propose a two hierarchy architecture to construct overlay network topology to resolve mismatch problem. The hosts in lower hierarchy are closest hosts. If the closed host can not be found in the lower hierarchy, they will search for high layer hierarchy to find the closed hosts. Based on the two hierarchy architecture, the locality of the hosts in overlay network can be realized to solve the mismatch problem.

Guoqiang Zhang *et al.*[25] propose a simple approach to solve mismatch problem by collecting global information from BGP table in Internet. The global information reveals the global information with respect to the hosts in the overlay network. Therefore, the topology-aware topology can be constructed in a simple way.

Zhichen Xu *et al.*[15] combine landmark clustering and RTT measurement have accuracy information to construct topology-aware overlay network topology. Kai Shen *et al.*[27] use landmark hierarchy information as the basis to construct self-organized DHT protocol to have better structured peer-to-peer overlay network topology. Sylvia Rantnasamy *et al.*[28] use landmark information to calculate the network latency and they present binning scheme to divide the hosts into different clusters based the landmark information. Therefore, the hosts in the same cluster will have short distance and the better overlay structure is established. Shansi Ren *et al.*[16] use the TTL-k flooding and RTT measurement to have the latency information within k hops. Based on the information, they will adaptive estimate the overlay network topology to solve mismatch problem. Demetrios Zeinalipour-Yazti *et al.*[30] propsoe domain name server ordering scheme to solve mismatch problem by helping with domain name server. The hosts have same domain name server ordering will be closed with respect to the underlying network topology.

The basic solution of the above literatures is to gather the topology status of the hosts in overlay network and then produces the optimized topology. The topology status is defined as the delay information between hosts. But in our opinion, the delay information just reveals the performance of the association path between hosts in overlay network and can not represent the actual topology of the overlay network. Therefore, our proposed method does not consider the delay information only and we also take the underlying network hop information into account.

3. PROPOSED METHOD

3.1. PROBLEM ILLUSTRATION

In previous work, most researchers use network latency or network delay as the measurement for host distance. In our work, we introduce hop-based solution as another viewpoint that is different from previous works. Network latency is calculated alone with a path from one host to another host, therefore, there exist some edges will be calculated more than ones so that this situation could be improved. In addition, the network latency is calculated more than ones, therefore, there exist redundant message transmission over the transmission path. We illustrate an example in Figure 7. There exist a overlay network include host A, host B and host C. Host B is the neighbor of host A and host C is the neighbor of host B. Host A resides on network node 1, host B resides on network node 4 and host C resides on network node 5. network node 2 and 3 might be router or gateway. We suppose host A send a message to host C via host B according to the overlay network in Figure 7. The message will be sent from network node 1→ network node 2→ network node 3→ network node 4→ network node 3 → network node 5. Therefore, we can find the revisit edges between network node 3 and network node 4. This might cause erroneous judgement of optimized topology.

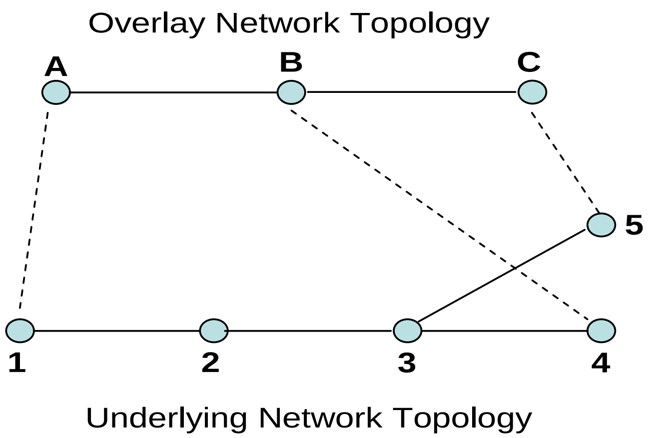


Figure 7 : An Example of Revisit Path

3.2. OVERLAY TOPOLOGY IMPROVEMENT SCHEME

3.2.1. NETWORK HOP TRACER MECHANISM

Based on our observation, we introduce network hop-based counting and detect the revisit edges along the query path to make the overlay network topology-aware. In practical, we can use network diagnose tool, *traceroute* or *tracert*, to explore the network path. These tools can trace the network address from source host to destination host so that the network hop can be recognized. Figure 8 is an example of that using *traceroute* tool from Minghsin University to Yahoo homepage.

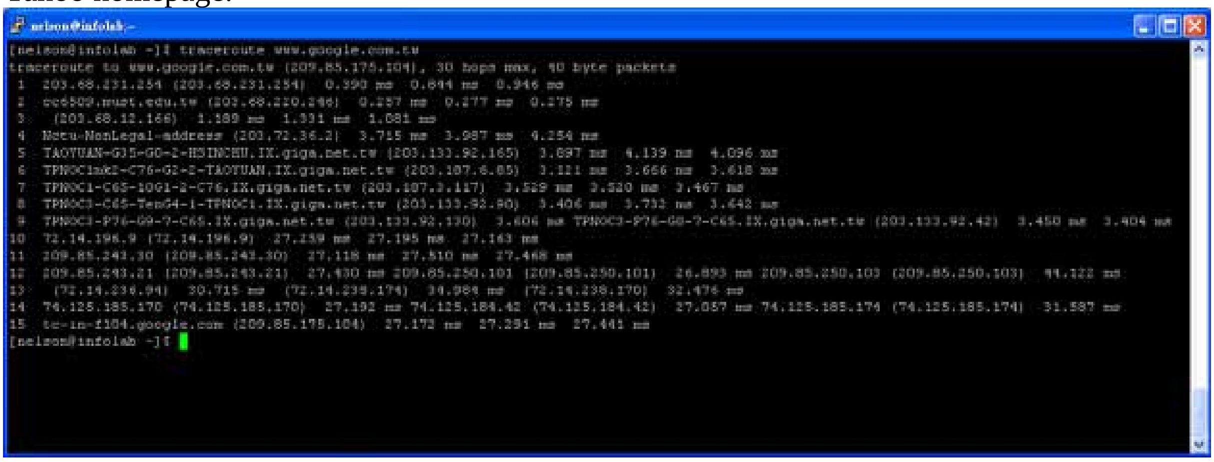


Figure 8 : *traceroute* tool Example from Minghsin University to Yahoo

Because query message is delivered from source host to destination host via some intermediate hosts, therefore, in order to obtain network hop information we design a *tracerHop-K* algorithm that is extended from the mechanism of *traceroute* or *tracert* tool to explore network hops between two hosts. Message delivery path is based on peer-to-peer overlay network topology, so the virtual delivery path is according to peer's connectivity in peer-to-peer overlay network. Each intermediate host on the path will execute *tracerHop-K* to get the network hop information to next host and then reply the network information to source host alone the message delivery path. For example, host A will have network hop information 1→2→3→4, and host b will have 4→3→5 and reply to host A. Figure 9 is an example of network hop information gathering process and Figure 10 is the illustration of the *tracerHop-K* algorithm.

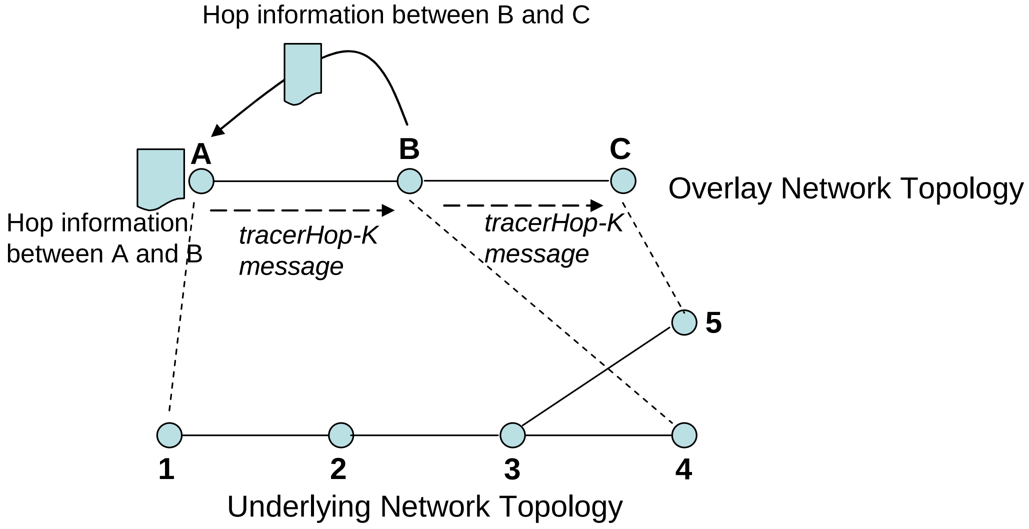


Figure 9 : Network Hop Tracer Example

INPUT : $ADDR_{dest}$, *K*
OUTPUT : $INFO_{hop}$
IF $ADDR != ADDR_{dest}$ *AND* $K > 0$
    $HOST_{next} \leftarrow FIND(TABLE_{host})$
    $INFO_{hop} \leftarrow traceroute(HOST_{next})$
    $K \leftarrow K - 1$
IF $K > 0$
    $SEND(HOST_{next})$

Figure 10 : *tracerHop-K* Algorithm

3.2.2. HOPK-BASED OPTIMIZATION SCHEME

In order to have topology-aware peer-o-peer overlay network, the host connection relationship that forming the peer-to-peer overlay network need to take underlying network information into account. Because peer-to-peer overlay network is a distributed architecture, each host is self-organized and self-managed so that having global underlying network information in peer-to-peer overlay network is a difficult process. Therefore, in our research we also use the similar concept that using local information to estimate global optimized topology. Each host will send a *tracerHop-K* message to have local network hop information within *K* host away from source host in peer-to-peer overlay network. After gathering the network hop information within the range of overlay network hop *K*, the host will construct an argument network topology which are connecting with peer-to-peer overlay network host and underlying network routers. Figure 11 is the example of argument network topology with 2 hops. The host with wathet blue color is the host that constructing the argument network topology for topology improvement. The host with red color is 1 hop from the wathet blue host and the host navy blue color is 2 hop from the wathet blue host. The black nodes are the router between adjacent hosts in peer-to-peer overlay network.

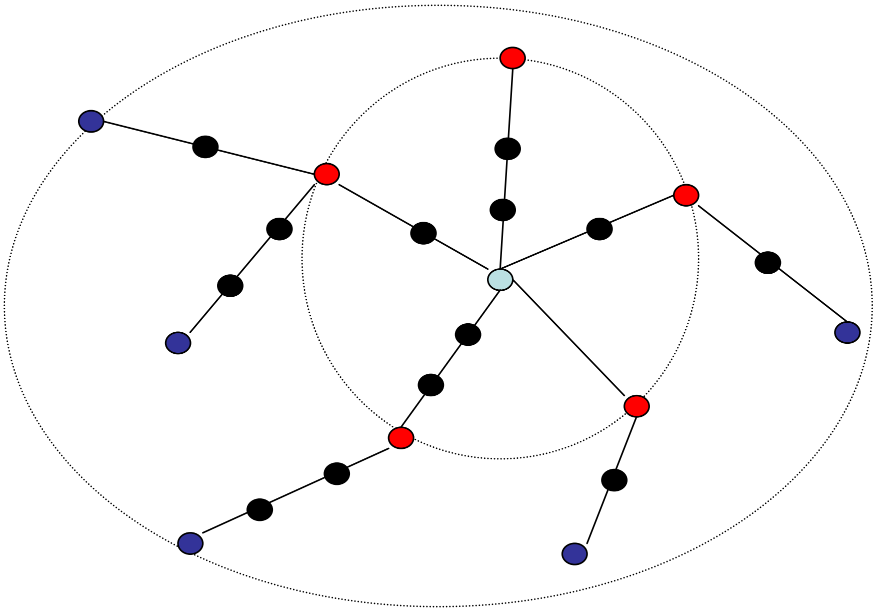


Figure 11 : Argument Network Topology Example

When the host constructs the argument network topology, the host will detect the repeat edges or cycle edges in the argument network topology and add the final host in the path to the host's neighbor. Figure 12 is the algorithm of the HopK-Based optimization scheme. The algorithm will be executed in each host of peer-to-peer overlay network periodically.

In general, the overall network is a summation of transmission delay, queuing delay, propagation delay and processing delay. Equation (1) is the formula that describes the overall network delay of peer-to-peer overlay network.

$$D_{network} = \sum_{1}^{n}\sum_{i}^{m} D_{host} = \sum_{1}^{n}\sum_{i}^{m} D_{t} + D_{q} + D_{p} + D_{pro} \qquad (1)$$

$D_{network}$ is the overall network delay of peer-to-peer overlay network. D_{host} is the network delay with respect to host of peer-to-peer overlay network. D_t is the transmission delay, D_q is the queuing delay, D_p is the propagation delay and D_{pro} is the processing delay. Because our method is to reduce the revisit edges when transmitting messages over peer-to-peer overlay network, the number of pass through router and the redundant messages are decreased. So the transmission delay, queuing delay, propagation delay and processing delay are decreased. Therefore, we can derive the result after using HopK-Based Optimization Scheme is better than before using HopK-Based Optimization Scheme simply.

```
function detect(PATH_{a->b})
begin
    for each HOST_i in PATH_{a->b}
        if HOST_i<>HOST_a and HOST_i<>HOST_b
            if predecessor(HOST_i) == successor(HOST_i)
                return true
            else
                return false
end
function Topology_Optimization
begin
    for each INFO_hop in Argument_Topology T
        for each HOST_i in INFO_hop
            if detect(PATH_{HOST->HOST_i})
                add HOST_i as HOST's neighbor
                break
end
```

Figure 12 : HopK-Based Optimization Scheme

4. PRACTICAL APPLICATION DEMONSTRATION

In previous sections, we have illustrated the scheme to resolve topology mismatch in peer-to-peer overlay network to improve the overall performance. In order to make the mechanism practical, we design an intelligent home environment in the following sub sections based on our propose scheme and UPnP protocol[17].

4.1 APPLICATION MOTIVATION

Because of the population of network usage, traditional home network have move on digital era. Home devices in the traditional home network are operating individually and can not communicate with other devices. Through network connection home devices will be connected with each other and work cooperatively. In order to provide seamless connection within home network, UPnP[17] is the most popular technology to realize the home network operations. The most important operation of UPnP technology is device/service discovery. Through device/service discovery, home devices can be aware which devices or services are available to use. However the device/service discovery mechanism is using broadcast messages. There are two major problems arising from the broadcast message. First, each device will send broadcast message to others, so that the network performance will be decreased. Second, because of broadcast message is sent over reserved broadcast IP address, therefore, broadcast message will not be sent across to other network segment. Otherwise, the router or gateway needs to be modified to support broadcasting across to other segments. So the heterogeneous environment will decrease the usage of home network.

Therefore, in order to resolve the above problem, we need to reduce the number of broadcast message and generic transportation architecture to support multi-segment network architecture and seamless connection between different network architecture. Fortunately, with the development of peer-to-peer overlay network architecture, multi-segment issue and seamless connection can be resolved easily without changing existing network design. In peer-to-peer network, messages can be relayed by intermediate peers and do not consider underlying network segment. Therefore, we take the advantage of the peer-to-peer overlay network architecture, we propose an implementation for UPnP operations over peer-to-peer overlay network. Through the implementation, the number of broadcast message will be reduced and message can be delivered without affecting by the mixed underlying network architecture.

On the other hand, when home user use their own mobile device, for example, PDA or mobile phone, to control home appliances within home network and move outside home network, home user will not control home device directly. Although we can deploy a home gateway to solve such kind of scenario, this will increase more complicate configuration and cost. Therefore, our work proposed in this research can meet the demand of flexible home usage also.

Besides the seamless integration of different network, to manipulate service easily is also a basic demand for home users and intelligent usage of home service is also an important feature to realize a smart home environment. In this paper, we also propose a service collaboration framework based on service planning to provide an easy use home environment for home users.

4.2. UPNP OPERATION OVER P2P

In this section, we reveal the design of the UPnP message transmission over peer-to-peer overlay network. The following sub-sections describe P2P-based UPnP device/service discovery and advertisement, UPnP service description acquiring, UPnP service control and event.

4.2.1. GENERIC MESSAGE MIDDLEWARE

When UPnP device join the home network, the UPnP device perform the join operation of peer-to-peer overlay network and establish the neighbor list of the UPnP devices. And then UPnP message could be sent over peer-to-peer overlay network. Originally, the UPnP message delivery will be sent via network interface directly. The solution of our propose method is to deliver UPnP message via peer-to-peer overlay network which do not need to consider the underlying network architecture. Figure 13 show the message flow over peer-to-peer network. When UPnP device send an UPnP message, the message will be transferred to peer-to-peer middleware which look up the address of destination device. If the middleware could not decide the destination address, the message will be sent to proper intermediate device to look up destination device via peer-to-peer routing mechanism and network transmission layer in advance. Therefore, the next device or destination device will be decided by the peer-to-peer middleware.

In order to avoid duplicate message received by nodes, each received message will be recorded in a receiving pool as a record by hash function. When message is received, the device calculates the hash value of the message and checks the hash value with receiving pool. If hash value is in the pool, the message will be dropped. Otherwise, the message will be processed. Figure 14 shows the overall processing flow chart with respect service discovery/advertisement, service description acquiring and service control.

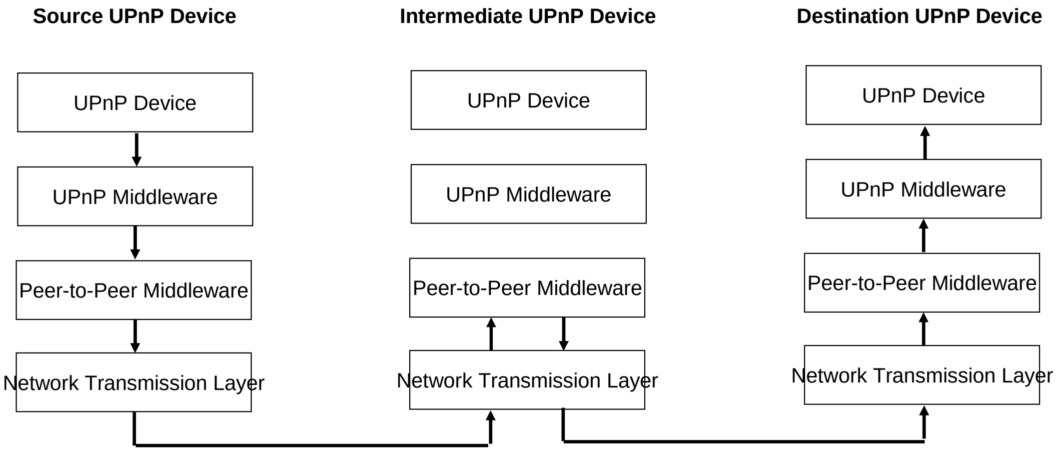


Figure 13 : Generic Message Middleware with P2P overlay network

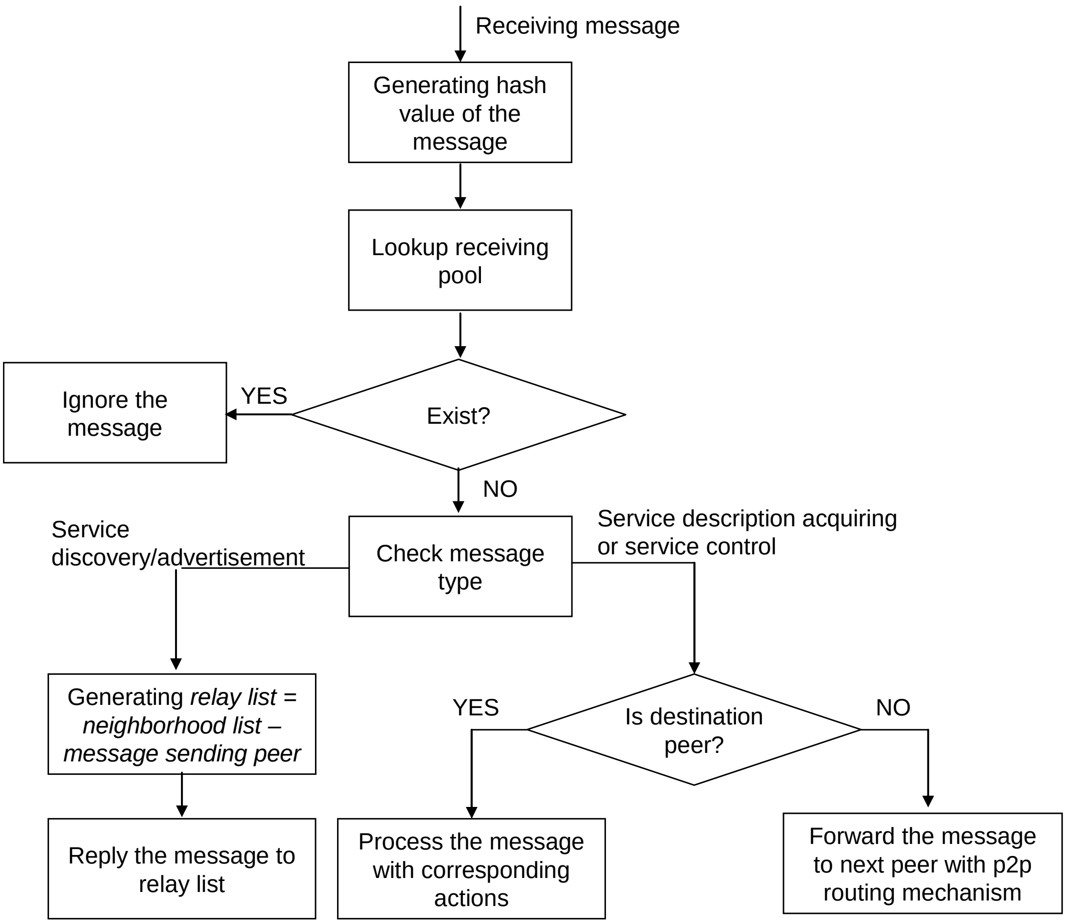


Figure 14 : Overall processing flowchart of UPnP message

4.2.2. SERVICE DISCOVERY AND ADVERTISEMENT

Device/service discovery and advertisement are the most important operation in UPnP. When UPnP device join or leave the home network, discovery and advertisement message is used to guarantee the availability of the devices. The discovery and advertisement mechanism comprise two kind of message including MSEARCH and NOTIFY.

If the device wants to know other devices, MSEARCH message will be sent. When MSEARCH message is sent, the message will be relayed to every node of the peer-to-peer overlay network. When a node receives the MSEARCH message, the node responses a reply message to the original node with its device identifier. Figure 15 shows the MSEARCH message over peer-to-peer network. Bold line is the MSEARCH message and dash line is the response message with respect to the MSEARCH message. From the figure, we can observe that intermediate node might receive several duplicate messages. As we described in previous section, first comes message will be processed and later duplicate message will be dropped. In addition, in order to avoid too many response messages on the same path, intermediate node will collect all response messages and package into one response message to the original sending node.

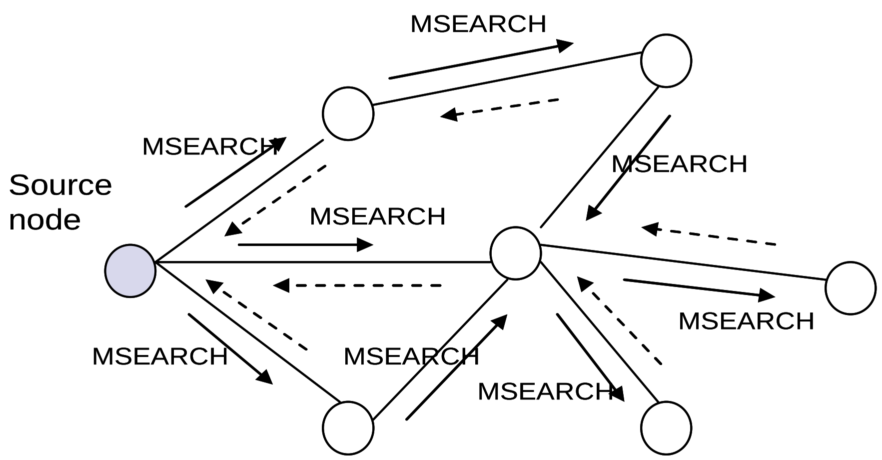


Figure 15 : MSEARCH message over P2P network

When UPnP device notify the awareness of the device actively, the NOTIFY message will be sent. When NOTIFY message is sent, the peer-to-peer middleware perform the join action to participate the device into peer-to-peer overlay network and intermediate node will relay NOTIFY message to its neighbors. Figure 16 shows the NOTIFY message over peer-to-peer network.

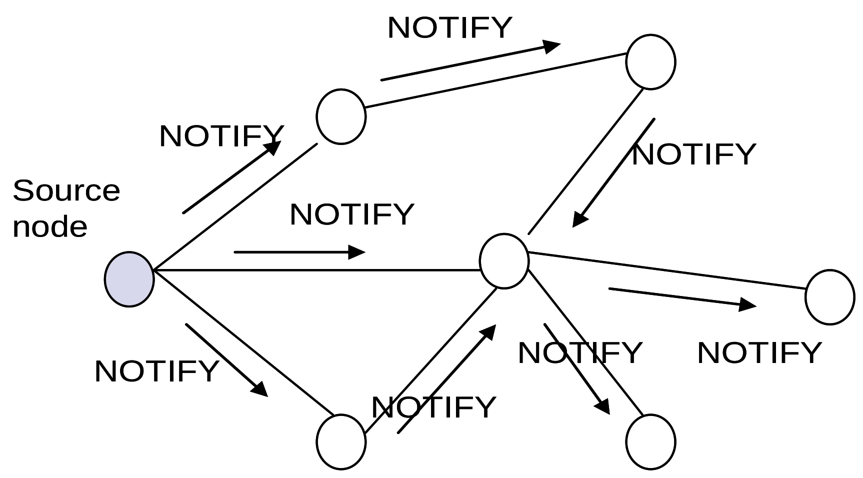


Figure 16 : NOTIFY message over P2P network

4.2.3. SERVICE DESCRIPTION ACQUIRING AND CONTROL

When peer has device identifier and related information, the peer can issue service acquiring message to get the service description over peer-to-peer overlay network. And then acquired node will reply the service description to the acquiring peer. The acquiring node will cache the service description in the available service pool for future usage. On the other hand, Service description acquiring is an end-to-end action, but devices are located in different network segment. Therefore, service description acquiring is still transmitted alone with peer-to-peer overlay topology. Figure 17 shows the service acquiring message over peer-to-peer network. Service control action is similar with service description acquiring operation which is an end-to-end action also. Therefore, when a node receives the service control command, the node will work according to the received service control command. Figure 18 shows the service control message over peer-to-peer network.

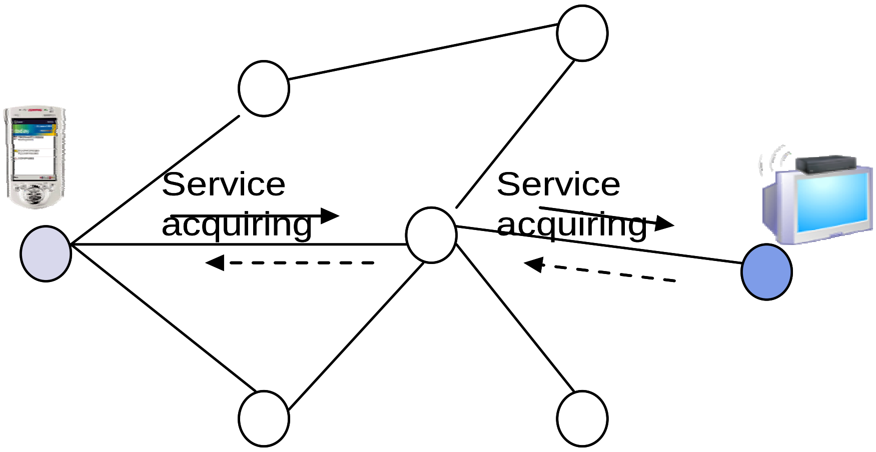


Figure 17 : Service acquiring message over P2P network

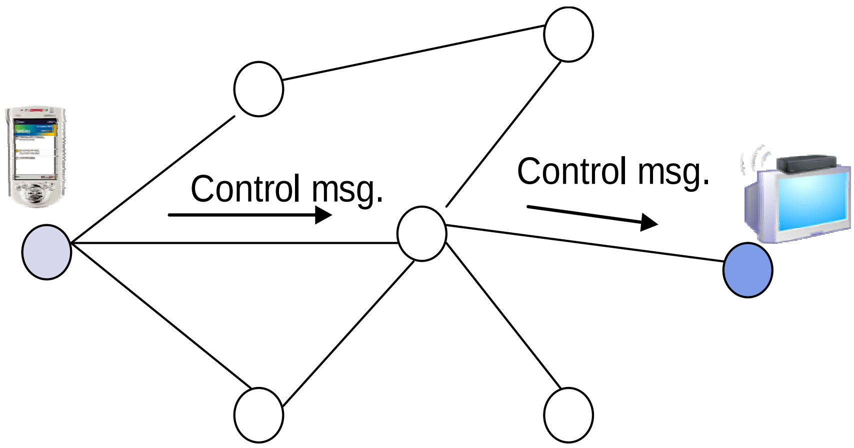


Figure 18 : Control message over P2P network

4.3. SMART HOME NETWORK ARCHITECTURE

In this section, we propose the design of the system architecture. First we will reveal the design of the protocol stack to realize the UPnP message over peer-to-peer network. And then the system software architecture which comprises several computing blocks or procedures will be showed.

4.3.1. PROTOCOL STACK

In order to make less modification on existing protocol stack, we insert an add-on peer-to-peer network middleware between UPnP middleware implementation and underlying TCP/IP protocol stack. The overall protocol stack is showed in Figure 19. The overall protocol stack

comprising four portions including user/vendor customization part, UPnP middleware, peer-to-peer network middleware and underlying TCP/IP stack.
User/vendor customization : Application developer can design their application with respect their scenario , idea or, usage. And they do not concern the detail of the underlying complex middleware or stack.
UPnP middleware : This is the traditional part of UPnP implementation including all functionalities of UPnP operations and messages.
Peer-to-peer network middleware : This portion is the basic transmission platform. This middleware will perform node joining, node leaving and topology maintenance. In addition, the peer-to-peer middleware will transmit the UPnP messages to destination node or route the message intermediate node also.
TCP/IP protocol stack : This is the actual network transmission layer. The destination node will be resolved by the peer-to-peer middleware and pass the destination node to the TCP/IP layer to perform actual packet transportation.

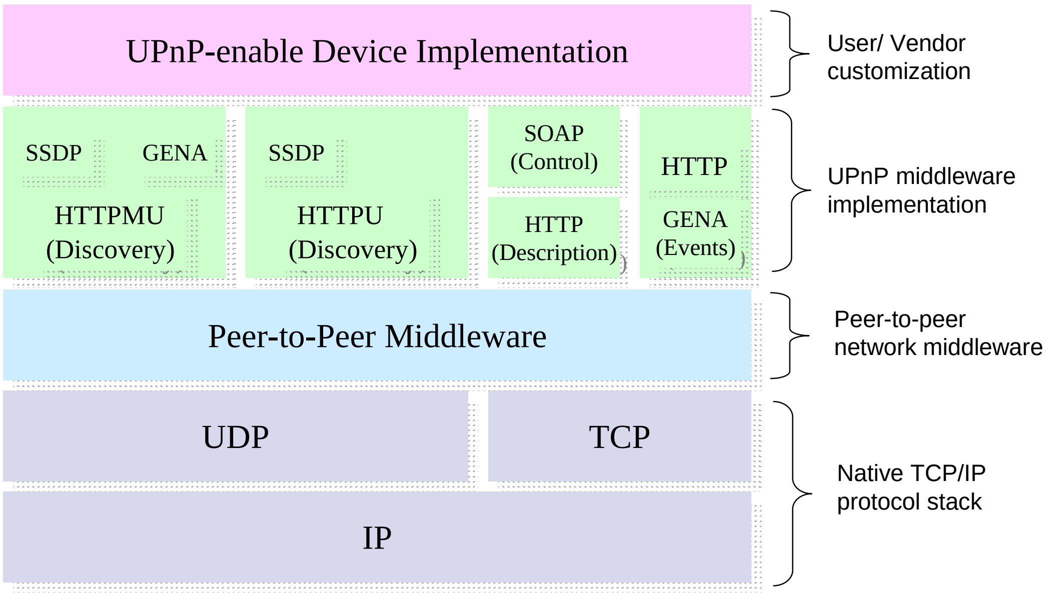


Figure 19 : Protocol stack illustration

4.3.2. SOFTWARE ARCHITECTURE

The protocol stack in previous section reveals the protocol architecture for realizing the home network scenario. In this section, we describe the software architecture for UPnP operations over peer-to-peer network. All messages are received and sent by the underlying network interface. The received packet will passed to message processor which perform message parsing and check whether the message is duplicate or not. Then the message will be passed to peer-to-peer lookup middleware to decide the packet will be relayed or be processing by the UPnP command dispatcher. The UPnP message dispatcher performs the major processing of the UPnP command and responsible for the corresponding actions. If the command is service advertisement, service discovery and service acquiring, the resolving result will be stored in the service pool. In addition, peer-to-peer lookup middleware will be responsible for peer-to-peer topology management, and peer join/leave processing. Figure 20 shows the proposed software architecture.

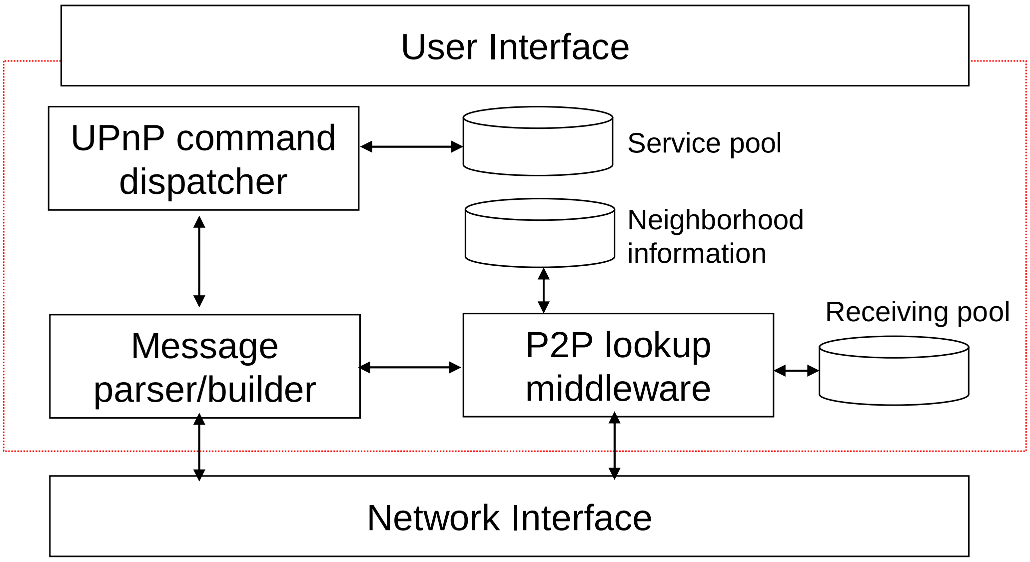


Figure 20 : The middleware software architecture

4.4. SERVICE COLLABORATION FRAMEWORK

In previous section, we have proposed the design of smart home environment based on peer-to-peer overlay network to seamless connecting home appliances in a feasible way. But in order to share and manipulate home service in a flexible approach, we propose a service collaboration framework in this section. Our proposed mechanism is based on service planning to have a collaboration diagram for home service so that the collaboration framework will reduce user effort. The general principle to achieve collaboration between different services on different home appliances is outlined as following.

Service preference : In order to describe different service capability or constrain, to have a easy understanding preference for service is very important. Fortunately, UPnP protocol described in previous section have defined service description based on XML language. The service preference can be described in common and easily.

Service workflow determination : Service is a basic unit for specified task in home environment. Home user will not understand each atomic service very well. And home user manipulates home service that comprises several services involving usually. Therefore to define a workflow that integrates each service is the tool for home users.

Service composition : After defining service workflow, different services can be composed from different home appliances as an atomic-like service so that user effort will be reduced and manipulate service in a more flexible way. The stage is to collect all of the available services and merge into service collaboration diagram.

Service execution : When service composition based on the service workflow, the composed service will be executed. And according to different service state in the service workflow, some of atomic service can be executed in parallel. Therefore, the service execution performance can be improved compared with traditional service manipulation which uses each service in step by step way. The service execution chain is called service execution flow.

4.4.1. SERVICE PLANNING

In order to make several services working cooperatively, we need to define a workflow is achieved by which services. At first we provide a service planning interface to home user to define service workflow. In the tool, home users just pick service component from the toolbar to link these picked service as an overall service flow. For example, we can consider the following scenario. A home user wants to watch a TV show on its PDA and wants to record the show in a storage place in home. Figure 21 shows the workflow of the above scenario and each circle represents a service task. The workflow will be called service planning in this paper. Service planning is high-level process to describe the service component which might be an atomic service or comprising sub-service components.

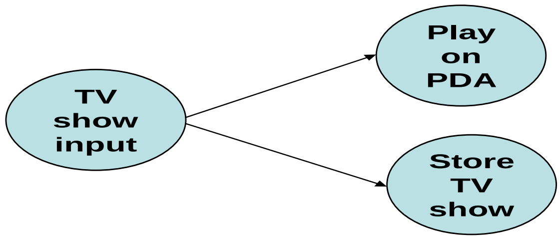


Figure 21 : Service Planning Example

4.4.2. SERVICE COMPOSITION MECHANISM

When the service planning is defined, the planning is complied as a service composition diagram. The compile process will recognize the planning into several detail service components and schedule different execution flow to produce different service diagrams that might have synchronous or asynchronous execution path. The service composition mechanism is a recursive process. Each service component from the service planning will be divided into more detail service component that might be atomic service or another service planning. Figure 27 illustrates the result of service diagram extraction process in a hierarchy architecture. The synchronous or asynchronous execution path is produced according to the following definition.

Definition 1 : Sequencing Flow - When the service A is followed service B, service B has a directed flow to service A. That is $A \rightarrow B$.

Definition 2 : Concurrent Flow - When service A and service B are independent, service diagram will split two concurrent flows to perform service A and B. That is $A \cap B = \phi$.

Figure 22~Figure 26 shows several service diagrams of the example that is described in previous sub-section. Service diagram I in Figure 22 means a video stream, called TV show in previous section, is the input for playing on the PDA and storing in home storage. Before playing on PDA, the video stream needs to be transferred to another format to play on PDA. On the other hand, video stream can be stored in home storage without transcoding. Service diagram II in Figure 23 means a video stream is the input for playing on the PDA and storing in home storage. Before storing in the home storage, the video stream needs to be transferred to another format. On the other hand, video stream can be played on PDA directly. Service diagram III in Figure 24 means video stream needs to be transferred to another format first and the format is suitable for both PDA and home storage. Service diagram IV in Figure 25 means the video stream needs to be transferred to another two formats to play on PDA and store in home storage. Because of the PDA and home storage require different video format. Service diagram V in Figure 26 means the video stream does not need to be transferred to another format and can be played on PDA and stored in home storage directly.

After service planning is divided as different service diagram representation, the home appliances will send the service query or discovery message to invoke service from other home appliances. After all atomic services are ready to execute, the overall service is prepared to be executed in next step.

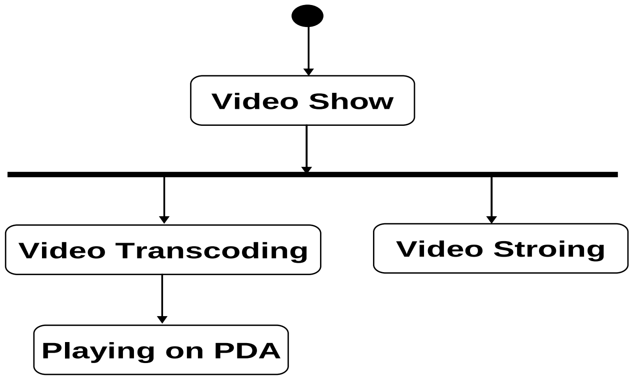


Figure 22 : Service Diagram I

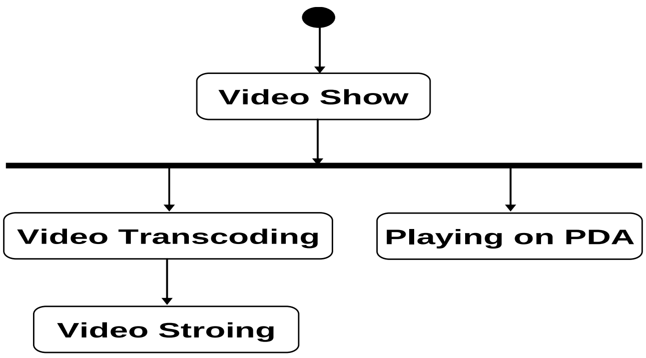


Figure 23 : Service Diagram II

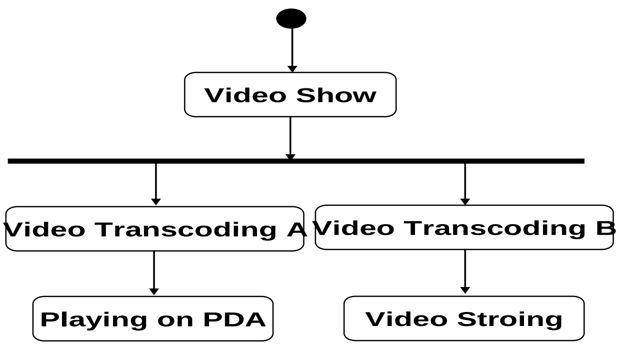


Figure 24 : Service Diagram III

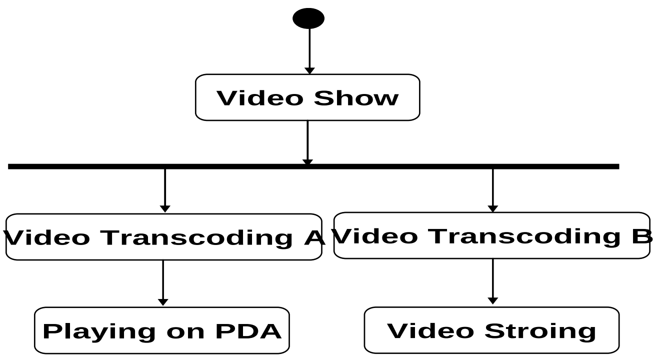


Figure 25 : Service Diagram IV

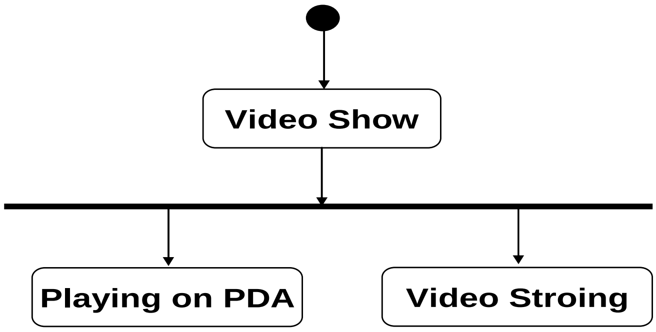


Figure 26 : Service Diagram V

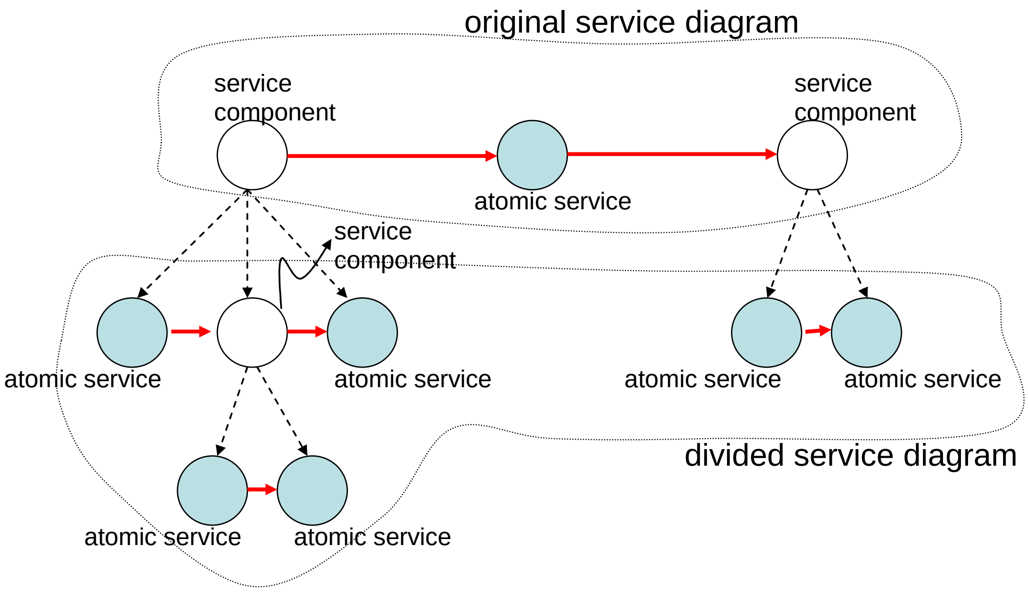


Figure 27 : Service Planning Example

4.4.3. SERVICE EXECUTION

After service composition mechanism by the service component extraction process, the service execution phase will compose the actual execution object for each service diagram. First, the service execution phase will send a service acquiring message to peer-to-peer based home environment to have all home appliances' status that will provide the service. After gathering all possible supported home appliances, the service execution phase will compute all possible service execution flow and compute the cost for each service execution flow. For example, if two service S1 and S2 can satisfy user's requirement, and home appliance A and B support service S1 and home appliance C and D provide service S2, the possible service execution flow will have four choices, that is (A, C), (A, D), (B, C) and (B, D). The service execution phase will select the minimum processing time of service execution flows. The service processing time is defined as the sum of the home appliances processing time and network processing time. The home appliances processing time will also be influenced by different home appliances' capabilities including the remained CPU time to process the service, the specified service processing time etc.. The network processing time includes all network delay, network unit processing time etc.. We will select the minimum cost from these service execution flows as the actual service execution flow. Equation (2) is the formula to compute processing cost with respect to each service execution flow.

$$Cost = \alpha \sum_i P_i + (1-\alpha) \sum_j L_j \qquad (2)$$

α is an estimated factor to represent the importance of the home appliance processing time and $0 \leq \alpha \leq 1$. $1-\alpha$ shows the importance factor of the network transmission. *Pi* is the home appliance processing time of device *i* and *Lj* is the network transmission time for edge *j* between two consequence execution devices. The network transmission time comprise the network delay, propagation delay and queuing delay.

4.4.4. IMPLEMENTATION

In previous sections, we have illustrated the major steps for collaborating services in home network. In order to build the service collaboration framework to process the results of each stages of service collaboration mechanism, we define several description languages to represent the results. All of designed description language is based on XML technology which is the famous and popular tool to design new description language in a flexible way. On the other hand, because the atomic service description and device description of UPnP-based home environment are also XML-based. Therefore, using XML technology as the core of the description language is the trivial method to implement the service collaboration framework. The complete set of description language in the service collaboration framework is showed in Figure 28. In service planning phase, Service Planning Description Language(SPDL) is used to produce Service Planning Description Document(SPDD) to illustrate the service planning. Figure 29 shows an example of Service Planning Description Document(SPDD) using Service Planning Description Language(SPDL). Service Diagram Description Language(SDDL) is used to produce Service Diagram Description Document(SDDD) to illustrate the service planning that can be performed by the different composition. Figure 30 shows an example of Service Diagram Description Document(SDDD) using Service Diagram Description Language(SDDL). Service Execution Description language(SEDL) is used to produce the Service Execution Description Document(SEDD) to illustrate the actual execution objects. Figure 31 shows an example of Service Execution Description Document(SEDD) using Service Execution Description language(SEDL).

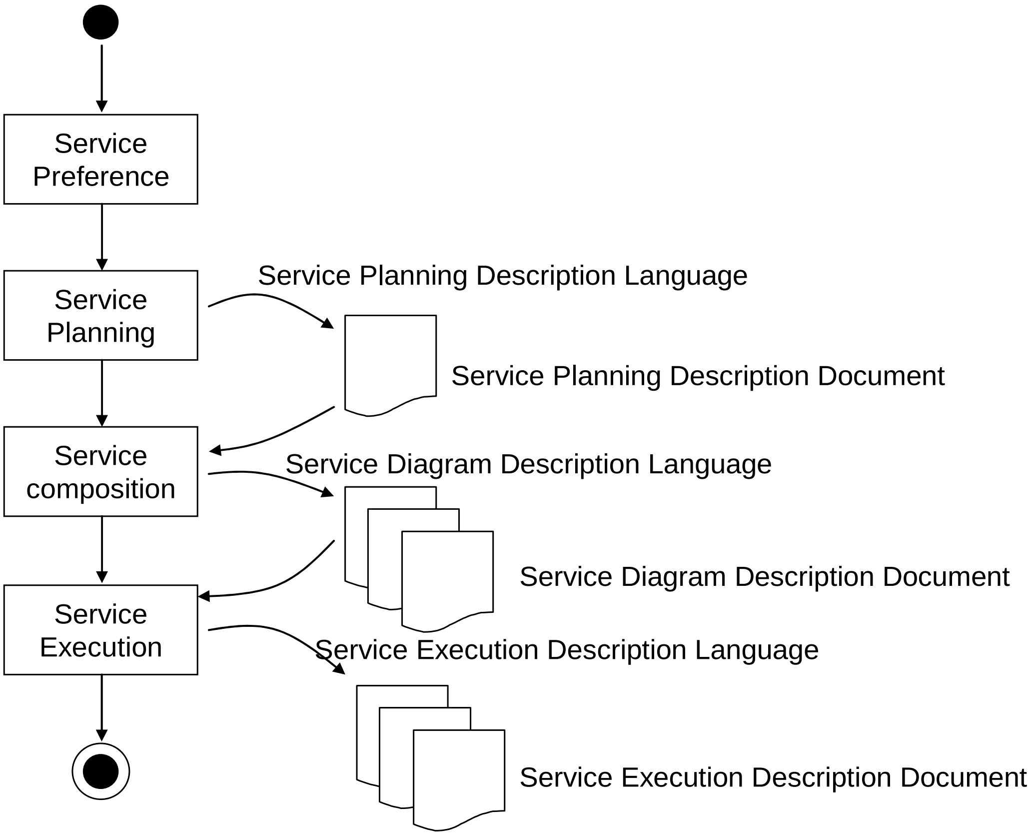


Figure 28 : Description Language Set of Service Collaboration Framework

```
<Service_Planning name="…..">
        <Service_Component>
                <Component_ID>…</Conponent_ID>
                <Component_Name>…</Component_Name>
                <Parent_Component>… </Parent_Component>
        </Service_Component>
        …Other Service Component……
</Service_Planning>
```

Figure 29 : An Example of Service Planning Description Document

```
<Service_Diagram name="…..">
        <Service_Planning_Name>…</Serivce_Planning_Name>
        <Service_List>
                <Sequence_Number>…</Sequence_Number>
                <Atomic_Service Name="…">
                        <Ancestor_Service>…</Ancestor_Service>
                        <Service_Action Name="…">
                                <Service_Parameter>
                                        <Paramter_Name>…</Parameter__Name>
                                        <Paramter_Value>…</Parameter__Value>
                                <Service_Parameter>
                                ….other service parameter…..
                        </Service_Action>
                        …other service action…
                </Atomic_Service>
                …other atomic service……
        </Service_List>
        …Other Service List……
</Service_Diagram>
```

Figure 30 : An Example of Service Execution Description Document

```
<Service_Execution Name="…..">
        <Execution_Flow Name="…" Sequence="…">
                <Atomic_Service Name="…">
                        <Ancestor_Service>…</Ancestor_Service>
                        <Device_URL>…<Device_URL>
                         <Service_Action Name="…" URL="…">
                                <Service_Parameter>
                                        <Paramter_Name>…</Parameter__Name>
                                        <Paramter_Value>…</Parameter__Value>
                                <Service_Parameter>
                                ….other service parameter…..
                        </Service_Action>
                        …other service action…
                </Atomic_Service>
                …other atomic service….
        </Execution Flow>
        …other service execution flow……
</Service_Execution>
```

Figure 31 : An Example of Service Diagram Description Document

5. CONCLUSION

In this research, we introduce using network hop information as the estimation factor to resolve mismatch problem between peer-to-peer overlay network and underlying network. From the transmission path analysis, we can discover the propose approach that can improve the peer-to-peer overlay network topology according to the network hop information between each virtual connection hosts. In order to make the method practically, we also propose a middleware implementation for home network to extend the UPnP operations which is originally restricted by broadcast message based on our proposed method. Based on the designed middleware using peer-to-peer overlay network, the home network message can be transmitted cross different network segment and do not need to modify the underlying network equipments. And based on the message transmission over peer-to-peer network, the number of broadcast message can be reduced and make the network usage efficient. On the other hand, in order to provide a smart home service environment, we also propose a service collaboration framework which is based on XML technology. Because our proposed middleware is based on peer-to-peer overlay network, there exists security issue including DoS attack between these peers. Therefore, a better security mechanism will be the most important task in the future. On the other hand, service planning in the service collaboration framework is generated by home users. In order to provide an automatic environment, service semantic composition is also a future research direction.

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APPENDIX

國際研討會論文發表一篇：

1. Chuan-Feng Chiu, Hsu, S.J., Sen-Ren Jan, "The design of UPnP-based home environment over peer-to-peer overlay network", The 2008 International Workshop on Mobile Systems, E-commerce and Agent Technology (MSEAT'2008) in conjunction with The First IEEE International Conference on Ubi-media Computing (U-Media'2008), July 15-16, 2008, pp.508-512

The Design of UPnP-based Home Environment over Peer-to-Peer Overlay Network

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Abstract

With the population of network usage, it is possible to connect home appliances with each other. The basic demand is to connect home appliances easily with less user intervening. UPnP is the most popular technology for realizing digital home. UPnP provide service and device discovery by sending broadcast message periodically. Therefore, this causes efficiency problem arising from many broadcast messages. In addition, home network is an emergence environment which might comprise several network architecture including ethernet, wireless network, or power-line etc.. Therefore, traditional broadcast will not work well in the complex network architecture. In order to solve the above problems, we propose a middleware implementation to realize UPnP operations over peer-to-peer overlay network.

1. Introduction

Because of the population of network usage, traditional home network have move on digital era. Home devices in the traditional home network are operating individually and do not have communication with other devices. Through network connection home devices will be connected with each other and work cooperatively. In order to provide seamless connection within home network, UPnP is the most popular technology to realize the home network operations. The most important operation of UPnP technology is device/service discovery. Through device/service discovery, home devices can be aware which devices or services are available to use. However the device/service discovery mechanism is using broadcast messages. There are two major problems arising from the broadcast message. First, each device will send broadcast message to others, so that the network performance will be poor. Second, because of broadcast message is sent over reserved broadcast IP address, therefore, broadcast message will not be sent across to other network segment. Otherwise, the router or gateway needs to be modified to support broadcasting across to other segments.

Therefore, in order to resolve the above problem, we need to reduce the number of broadcast message and generic transfer architecture to support multi-segment network architecture. Fortunately, with the development of peer-to-peer overlay network architecture multi-segment issue can be resolved easily. In peer-to-peer network, messages can be relayed by intermediate peers and do not consider underlying network segment. Therefore, we take the advantage of the peer-to-peer overlay network architecture, we propose an implementation for UPnP operations over peer-to-peer overlay network. Through the implementation, the number of broadcast message will be reduced and message can be delivered without considering the underlying multi-segment architecture.

On the other hand, when home user use their own mobile device, for example, PDA or mobile phone, to control home appliances within home network and move outside home network, home user will not control home device directly. Because UPnP do not work well between in-home and outside-home. Although we can deploy a home gateway to solve such kind of scenario, this will increase more complicate configuration and cost. Therefore, our work proposed in this paper can meet the demand of flexible home usage also.

The rest of this paper is organized as followings. Section 2 will reveal UPnP and peer-to-peer overlay network concept, and related research on home network. Section 3 describes the design of UPnP operations over peer-to-peer overlay network. Section 4 describes the system architecture of the proposed implementation. Finally, we give a brief conclusion of our work in section 5.

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2. Related work

UPnP[1] is the most popular implementation to realize home network and it can enable data communication between home devices via a set of UPnP commands. The major operations including service discovery, service advertisement service acquiring and service control and these operations are transmitted over HTTP protocol. UPnP comprise several standards such as Simple Device Discovery Protocol, Simple Object Access Protocol and General Notification Architecture to perform service discovery, service description acquiring and service control and notification. Two kinds of roles are defined in UPnP. One is UPnP Control Point and the other is UPnP Device. UPnP Control Point is the device that can issue manipulation command to ask UPnP device to perform some actions. And UPnP Device is to provide the available services for UPnP Control Point. Figure n is the general representation between UPnP Control Point and UPnP Device.

Peer-to-peer network is a popular virtual network architecture in recent year. It can provide resource sharing in a distributed way. It resides on underlying network architecture and is a distributed architecture without central server involving. The first peer-to-peer network is Napster[4]. It deploy a central server as an index server, each peer can find the location of interest data items from the index server and contact the corresponding peer directly. With the development of peer-to-peer network, two peer-to-peer network architectures are appeared. One is Unstructure peer-to-peer network and the other is Structure peer-to-peer network. Gnutella[3] is such kind of Unstructure peer-to-peer network. Peers are connected in a distributed way and do not need to know overall topology. It uses flooding as the mechanism to send query to find the related information. In Structure peer-to-peer network, it assign *key* to the data and compute a *value* for the *key*. The *(key, value)* pair is used for retrieving and locating the data item on a peer. CAN[5], Chord[6], Pastry[7] and Tapestry[8] are the famous Structure peer-to-peer network system. Unlike flooding in Unstructure peer-to-peer network, Structure peer-to-peer network routing can be bounded in *O(logN)* hops.

3. UPnP operations over P2P

In this section, we reveal the design of the UPnP message transmission over peer-to-peer overlay network. The following sub-sections describe P2P-based UPnP device/service discovery and advertisement, UPnP service description acquiring, UPnP service control and event.

3.1. Generic message middleware

When UPnP device join the home network, the UPnP device perform the join operation of peer-to-peer overlay network and establish the neighbor list of the UPnP devices. And then UPnP message could be sent over peer-to-peer overlay network. Originally, the UPnP message delivery will be sent via network interface directly. The solution of our propose method is to deliver UPnP message via peer-to-peer overlay network which do not need to consider the underlying network architecture. Figure 1 show the message flow over peer-to-peer network. When UPnP device send an UPnP message, the message will be transferred to peer-to-peer middleware which look up the address of destination device. If the middleware could not decide the destination address, the message will be sent to proper intermediate device to look up destination device via peer-to-peer routing mechanism and network transmission layer in advance. Therefore, the next device or destination device will be decided by the peer-to-peer middleware.

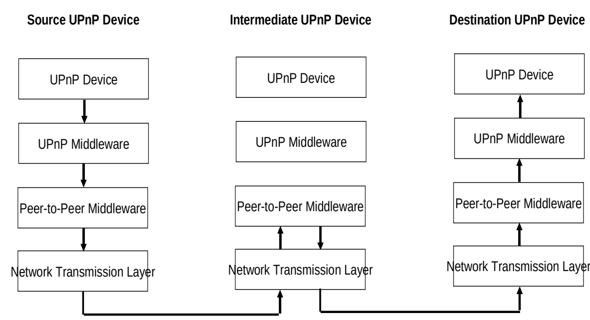

Figure 1. UPnP message over P2P network

In order to avoid duplicate message received by nodes, each received message will be recorded in a receiving pool as a record by hash function. When message is received, the device calculates the hash value of the message and checks the hash value with receiving pool. If hash value is in the pool, the message will be dropped. Otherwise, the message will be processed. Figure 2 shows the overall processing flow chart with respect service discovery/advertisement, service description acquiring and service control.

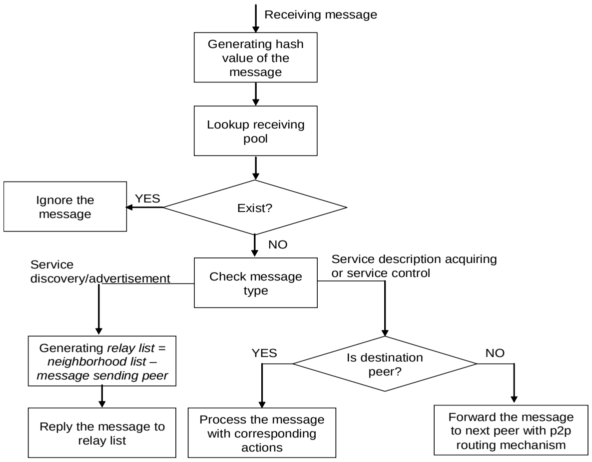

Figure 2. Overall processing flowchart of UPnP message

3.2. Service discovery and advertisement

Device/service discovery and advertisement are the most important operation in UPnP. When UPnP device join or leave the home network, discovery and advertisement message is used to guarantee the availability of the devices. The discovery and advertisement mechanism comprise two kind of message including MSEARCH and NOTIFY.

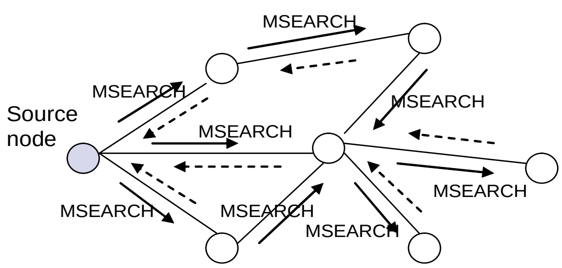

Figure 3. MSEARCH message over P2P network

If the device wants to know other devices, MSEARCH message will be sent. When MSEARCH message is sent, the message will be relayed to every node of the peer-to-peer overlay network. When a node receives the MSEARCH message, the node responses a reply message to the original node with its device identifier. Figure 3 shows the MSEARCH message over peer-to-peer network. Bold line is the MSEARCH message and dash line is the response message with respect to the MSEARCH message. From the figure, we can observe that intermediate node might receive several duplicate messages. As we described in section 3.1, first comes message will be processed and later duplicate message will be dropped. In addition, in order to avoid too many response messages on the same path, intermediate node will collect all response messages and package into one response message to the original sending node.

When UPnP device notify the awareness of the device actively, the NOTIFY message will be sent. When NOTIFY message is sent, the peer-to-peer middleware perform the join action to participate the device into peer-to-peer overlay network and intermediate node will relay NOTIFY message to its neighbors. Figure 4 shows the NOTIFY message over peer-to-peer network.

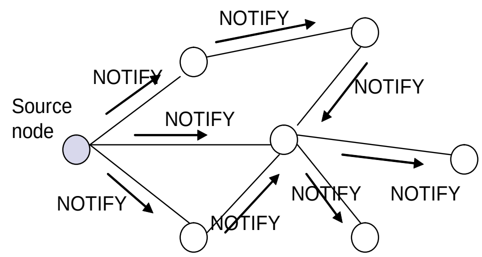

Figure 4. NOTIFY message over P2P network

3.3. Service description acquiring and control

When peer has device identifier and related information, the peer can issue service acquiring message to get the service description over peer-to-peer overlay network. And then acquired node will reply the service description to the acquiring peer. The acquiring node will cache the service description in the available service pool for future usage. On the other hand, Service description acquiring is an end-to-end action, but devices are located in different network segment. Therefore, service description acquiring is still transmitted alone with peer-to-peer overlay topology. Figure 5 shows the service acquiring message over peer-to-peer network. Service control action is similar with service description acquiring operation which is an end-to-end action also. Therefore, when a node receives the service control command, the node will work according to the received service control command. Figure 6 shows the service control message over peer-to-peer network.

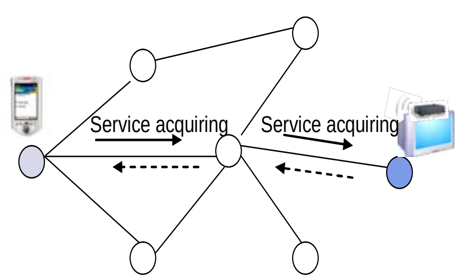

Figure 5. Service acquiring message over P2P network

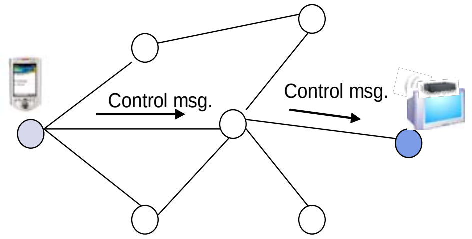

Figure 6. Control message over P2P network

4. System architecture

In this section, we propose the design of the system architecture. First we will reveal the design of the protocol stack to realize the UPnP message over peer-to-peer network. And then the system software architecture which comprises several computing blocks or procedures will be showed.

4.1. Protocol stack

In order to make less modification on existing protocol stack, we insert an add-on peer-to-peer network middleware between UPnP middleware implementation and underlying TCP/IP protocol stack. The overall protocol stack is showed in Figure 7. The overall protocol stack comprising four portions including user/vendor customization part, UPnP middleware, peer-to-peer network middleware and underlying TCP/IP stack.

User/vendor customization : Application developer can design their application with respect their scenario , idea or, usage. And they do not concern the detail of the underlying complex middleware or stack.

UPnP middleware : This is the traditional part of UPnP implementation including all functionalities of UPnP operations and messages.

Peer-to-peer network middleware : This portion is the basic transmission platform. This middleware will perform node joining, node leaving and topology maintenance. In addition, the peer-to-peer middleware will transmit the UPnP messages to destination node or route the message intermediate node also.

TCP/IP protocol stack : This is the actual network transmission layer. The destination node will be resolved by the peer-to-peer middleware and pass the destination node to the TCP/IP layer to perform actual packet transportation.

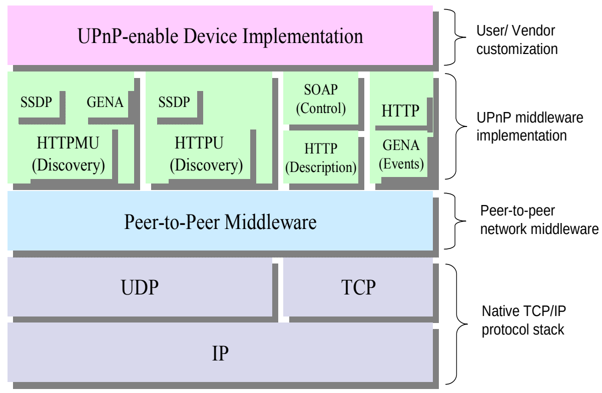

Figure 7. Protocol stack illustration

4.2. Software architecture

The protocol stack in previous section reveals the protocol architecture for realizing the home network scenario. In this section, we describe the software architecture for UPnP operations over peer-to-peer network. All messages are received and sent by the underlying network interface. The received packet will passed to message processor which perform message parsing and check whether the message is duplicate or not. Then the message will be passed to peer-to-peer lookup middleware to decide the packet will be relayed or be processing by the UPnP command dispatcher. The UPnP message dispatcher performs the major processing of the UPnP command and responsible for the corresponding actions. If the command is service advertisement, service discovery and service acquiring, the resolving result will be stored in the service pool. In addition, peer-to-peer lookup middleware will be responsible for peer-to-peer topology management, and peer join/leave processing. Figure 8 shows the proposed software architecture.

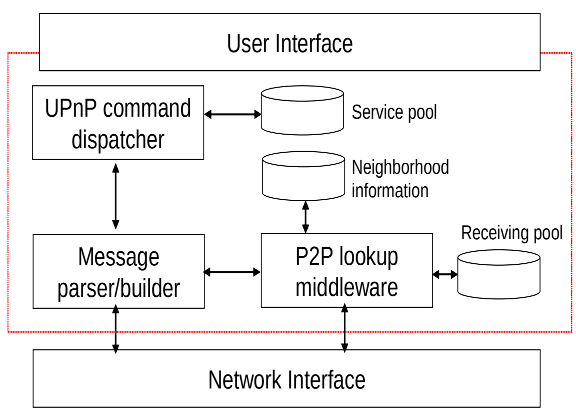

Figure 8. The middleware software architecture

5. Conclusion

In this paper, we propose a middleware implementation for home network to extend the UPnP operations which is originally restricted by broadcast message. Based on the proposed middleware, the broadcast message can be transmitted cross different network segment and do not need to modify the underlying network devices. And based on the message transmission over peer-to-peer network, the number of broadcast message can be reduced and make the network usage efficient. In the future, in order to make service usage more efficient, automatic and intelligent service cooperation is an important issue. On the other hand, because our proposed middleware is based on peer-to-peer overlay network, there exists security issue including DoS attack between these peers. Therefore, a better security mechanism will be the most important task in the future.

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