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Service-oriented networking platform on smart devices

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Abstract: This study presents the design of a service-oriented networking platform to offer dynamic networking services in support of mobile group communications among connected smart devices. This platform enables users to access smart services anywhere and anytime with embedded devices while satisfying their requirements of various smart services. The proposed platform adopts a session initiation protocol (SIP) protocol as service signalling protocol that provides high extensibility and compatibility with an existing service system. The overlay network structure suggested in our platform provides an advantage of building a scalable and dynamic service network based on multiple smart zones. Furthermore, the quality of end-to-end service in dynamic network environments is guaranteed by virtue of the smart delivery scheme in the platform.

1 Introduction

In the near future, many kinds of embedded devices or computers are expected to create pervasive computing environments [1]. Pervasive computing will enable end users to access a large amount of information data and obtain various services anywhere and anytime via any device, while the complex interfaces of access to services are effectively invisible to them with the help of utilising advanced technologies in our environments [2]. These trends have brought not only the change into the human-centred access way of information [3], but also the occurrence of emerging technologies such as machine-to-machine (M2M) communication or multi-hop paradigm in mobile *ad-hoc* networks. The technology of mobile multi-hop networking is essential in pervasive computing environments where devices self-organise a local network to support interactions among users [4]. The characteristics of this multi-hop networking can be naturally combined with user behaviours and daily life events by accepting the human-centric networking paradigm being triggered from the increase of mobile devices. For this reason, the networking paradigm based on those devices is shifting from device-to-device towards human-to-human networking and is also moving to service-oriented networking being centred during communication between people's mobile devices [5].

In pervasive computing environments, devices can be located anywhere and service networks can be dynamically constructed by the devices [6]. In these dynamic network environments, users want to obtain the same service without being interrupted even if they change a device or move to a different network environment. Therefore the needs of dynamic networking service that can accept such user demands and changes of network topology are more increasing. However, with the existing service signalling and transmission technology applied in dynamic network environments, there is a problem that communications among devices in a service group become unstable and in turn users may be unsatisfied with the quality of a service. In order to overcome this problem, our platform introduces the concept of service-oriented networking that provides dynamic networking services requested by service users. When a user with smart device or intelligent machine enters into a new environment and wants to obtain services in a surrounding area, the service consumers need the convenient means of finding the service content related to user-specific context [7, 8]. Therefore the service-oriented networking platform should recognise the needs of service consumers under their current situation by means of context awareness [9, 10] and provide proper services according to changing context [11] of service consumers.

The M2M [12, 13] is one of the potential technologies to evolve pervasive computing and its applications, and will become a hot topic in the next generation of computing and communication networks [14]. The M2M services [15, 16] are expected to give a great impact on our daily lives by enabling communication among smart objects, and lead to an emerging market to provide various services ranging from mobile *ad-hoc* networking to sensor networking service for monitoring geographical or seismic activities. The embedded devices of our daily lives in the upcoming smart environments such as at smart home [17] or building will become proactive actors that can provide or consume information or service. The dynamic and heterogeneous characteristics of M2M network [18, 19] increase the complexity in the provision of smart services. For this reason, the realisation of M2M in pervasive computing environments poses several challenges about seamless integration, heterogeneity, scalability and mobility. Therefore the overlay network architecture that enables the service discovery among interactive heterogeneous devices [20] is necessary, when a huge number of various devices are connected to form the M2M network. In addition, in order to provide the desired quality of service (QoS) in various devices of the M2M network, the service signalling protocol independent of service types, device types and access networks is required and the capability differences of heterogeneous devices should be considered.

For these ultimate goals, this paper proposes the design of service-oriented networking platform supporting uniform service signalling and smart content delivery in the heterogeneous network environments. Our platform adopted a SIP [21] protocol of providing a high flexibility and extensibility as a service signalling protocol in order to be compatible with an existing service system. It improves the flexibility and scalability of service network by constructing a service overlay network based on multiple smart zones, and guarantees the quality of end-to-end service by applying a robust content transmission scheme.

This paper is organised as follows. Section 2 presents the architecture of service-oriented networking platform. Section 3 describes the functions of dynamic service signalling and smart content delivery to support the interconnection of numerous intelligent devices and to provide smart services in heterogeneous network environments. Section 4 demonstrates the feasibility of our presented platform as the proof-of-concept prototype by experiment. Finally, Section 5 concludes the paper with some suggestions for future work and research directions.

2 Platform architecture for the dynamic networking service

To enable users to experience a variety of personalised services seamlessly across heterogeneous networks, our approach proposes the service-oriented networking platform which satisfies the following key requirements for interoperability, scalability, smartness and invisibility of the convergence service:

- *Interoperable signalling over heterogeneous networks:* The platform should use the extended version of an existing protocol as a unifying protocol to create the service overlay network without modification of existing network infrastructures.
- *Scalable networking of diverse devices:* The key requirement of the platform is the ability to connect various types of devices with each other and support service adaptation according to the capability of devices.
- *Smart delivery of various contents:* To deliver service information efficiently to the corresponding user in right time and place, a robust data transmission method should be applied depending on service characteristic and network status.
- *Context awareness of user-centric environment:* The user-specific service should be provided considering the current user context such as spatial or temporal information, device condition and physiological information.

Based on these requirements, our approach focuses on designing a novel architecture of the platform to build a service network by using the extended version of an existing protocol and to provide automated services dynamically in heterogeneous networks. Our platform uses a reconfigurable and scalable SIP-compatible protocol so that it can provide the user-friendly services minimising interactive user interfaces by exchanging service signalling messages including context information.

To enhance scalability and availability of the service network structure for dynamic mobile devices, our proposed platform constructs an overlay network for a convergence service by forming several non-overlapping groups called ‘smart zones’. In order to propagate session information to devices in a service group efficiently, it maintains the service overlay network by limiting the amount of control information being exchanged and reducing the control overhead of signalling through the structured service network based on multiple smart zones. The framework of this structured service network enables mobile devices to discover each other by forming and maintaining multiple smart zones. Furthermore, this framework enables the devices in a service group to establish a service session or conference and to exchange messages by finding the shortest network path in multiple smart zones.

As shown in Fig. 1, the architecture of the proposed platform supports the interacting operations of components and enables service signalling control, smart object management, smart content transmission and context-aware computing. The proposed platform uses an extended SIP [22] as a common signalling protocol for convergence services in order to form a smart zone dynamically and maintain the connections with neighbouring smart zones. While constructing the service overlay network based on multiple smart zones, each mobile device obtains object ID, zone ID and information about the other devices within the zone where the mobile device currently participates. In addition, during the signalling processes forming smart zones based on the overlay network structure, mobile devices play different roles, such as ‘smart object, smart zone manager, smart zone router or signalling gateway’ depending on situation. The zone ID and the role of each device may be changed if the service network environment rapidly changes. Even though the mobile user moves from one smart zone to another, the session of on-going convergence service is preserved by the signalling interaction of the following platform components:

- *Smart object:* It sends a signalling message for service requests or responds to the received signalling message to provide the requested service over the overlay network even if moving between smart zones.
- *Smart zone manager:* It is a local coordinator which manages device members in a smart zone and performs the intra-zone transmission. It should manage dynamic members in the smart zone efficiently because they join or leave any smart zone freely.
- *Smart zone router:* It acts as a bridge between smart zones. It shares the information of adjacent smart zones with each other so that it can access the information and forward signalling or data packets between smart zones.
- *Signalling gateway:* It translates a service signalling to be compatible with the signalling of infrastructure networks. In addition, this component performs the role of a representative device so that it looks like a remote mobile device connected to the same networks. All packets being sent to a remote mobile device in infrastructure networks are passed through the signalling gateway.

The scheme of our proposed platform makes the service overlay network much simpler and reduces packet collision by limiting control traffic through the backbone network structure consisting of smart zone managers and smart zone routers. Even if position or status of devices changes, the overlay network structure of multiple smart zones affects only some of logical network paths and the service network is maintained in a stable manner. Thus, our platform not only can build the convergence service network autonomously with no infrastructure, but it can also construct the large-scale convergence service network compatible with the current infrastructure.

3 Dynamic service signalling and smart content delivery

This section describes the signalling flow of session setup and management for providing a dynamic networking service of participative devices in heterogeneous network environments. Next, the flow of a smart algorithm to improve the end-to-end QoS through the QoS-aware transmission scheme in dynamic network environments is explained.

3.1 SIP signalling for services discovery and provision

To support a dynamic networking service of participative devices, the proposed platform uses an extended SIP as the protocol of service signalling in distributed network environments. By using the extended SIP, it performs the functions of signalling processing for device discovery, service publication and the management of multi-party service sessions. As registrar and proxy servers for a SIP service are not present in the fully distributed network environments such as *ad-hoc* networks, the functions of SIP proxy and registrar servers are embedded in the service platform of each mobile device. Furthermore, the proposed platform builds a service overlay network in order to interoperate the function modules of SIP servers which are spread over all devices in distributed network environments.

As shown in Fig. 2*a*, the smart zone manager and smart zone router in our proposed platform manage the smart zone-based information of intra-zone and neighbour-zone objects. They also participate in propagation of control/update messages for routing in order to construct a service backbone network. The structure of this role separation in our platform propagates the control

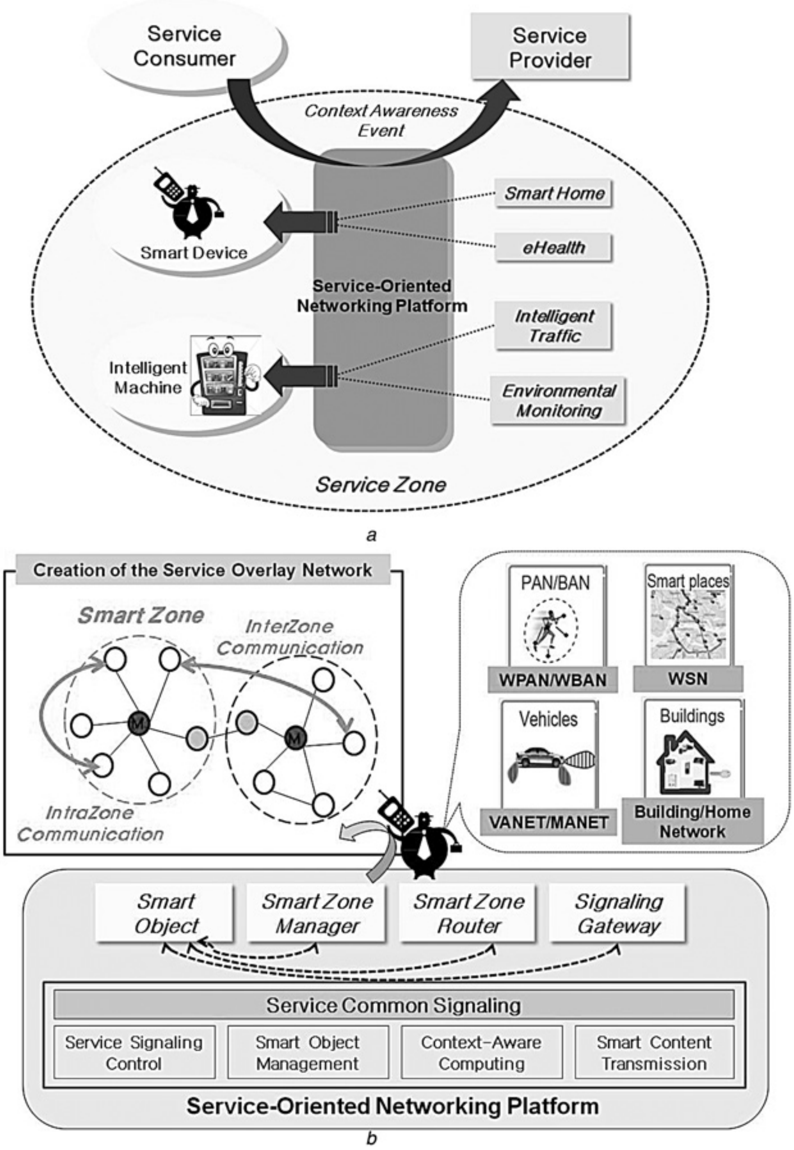


Fig. 1 *Service-oriented networking platform*

a Concept of service-oriented networking
b Architecture of service-oriented networking platform

information efficiently and reduces routing overhead by limiting the amount of control messages to be exchanged.

In our proposed platform, each device transmits the extended SIP message of OBJECT_INFO to its one hop neighbour devices for a announcing its presence. Each device creates or updates its adjacency table on receipt of these messages from its neighbour devices. After OBJECT_INFO_INTERVAL time interval, each device retransmits OBJECT_INFO messages containing the information of adjacency tables. In each smart zone, a device connected with many adjacent devices is elected as a smart zone manager to manage all devices in a smart zone. The smart zone manager broadcasts a ZONE_INFO message in order to create and manage a smart zone. When receiving a ZONE_INFO message from the smart zone manager of a smart zone being identified by a zone-ID header field of the ZONE_INFO, neighbour devices send a response message (200 OK or 606 Not Acceptable) according to whether they wish to join. After the signalling process mentioned earlier, our service platform organises a large number of devices into multiple smart zones and each smart zone is self-governed by exchanging the extended SIP messages such as OBJCET_INFO and ZONE_INFO. The size of a smart zone depends on the number of hops in the smart zone and the transmission range of mobile devices.

All devices in a smart zone register their location information into the SIP registrar module of a smart zone manager, by replying to the ZONE_INFO with a 200 OK message containing the contact information of a replying device. In addition, the contact information of registered devices is spread to other devices in a smart zone through the zone-member header field of the next transmitting ZONE_INFO message. Through this signalling process, our service platform provides the distributed location service by embedding the function of SIP registrar into a smart zone manager of each smart zone.

The smart zone router is a bridging device that can hear the information of members from one or more neighbour smart zones. When an OBJECT_INFO message is received from a neighbour device in other smart zone, a device perceives oneself as a smart zone router by comparing the ID of current smart zone with a zone-ID header field, and then transmits the OBJECT_INFO message including the object-type header field of ‘sZone_router’ value. Furthermore, the smart zone routers can share the information of device members with each other by sending a NEIGHBOR_INFO message including the zone-member header field to adjacent smart zone routers.

Our proposed platform can support the mobility recognition of smart devices exchanging the ZONE_INFO request/response

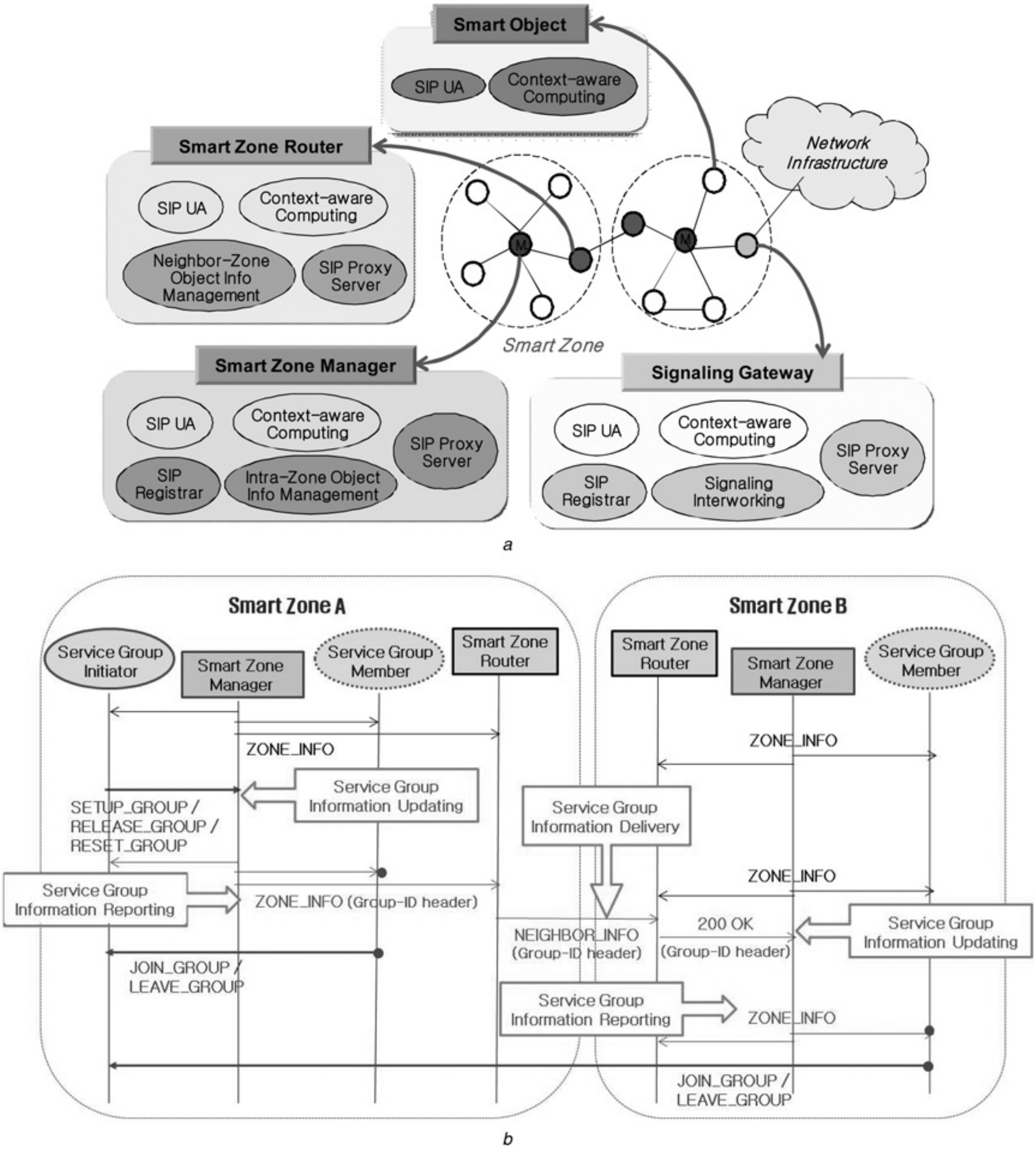


Fig. 2 *SIP signalling for the provision of dynamic networking service*

a SIP-based detailed modules in service-oriented networking platform
b Signalling flow of the group-based service in multiple smart zones

messages periodically in smart zones. In each smart zone, a smart zone manager recognises the corresponding device as a disappeared or moved object in case of no reply to a ZONE_INFO request and as a newly joined object in case of a new reply to this request. If there is no transmission of ZONE_INFO message for a long time by sudden failure or low battery of a smart zone manager, a new smart zone manager is elected among the candidate devices in a smart zone.

In the proposed platform, the signalling gateway announces the information of its address through a response message with an object-type header field of 'signaling_gw' value while replying to the ZONE_INFO message periodically received from a smart zone manager. When receiving the reply from the signalling gateway, the smart zone manager broadcasts the updated ZONE_INFO to other devices in the smart zone after inserting the signalling gateway's address into the GW-INFO header field of its next ZONE_INFO message. As a consequence of these processing, the signalling gateway's information including ID and address is spread in its smart zone and adjacent smart zones, and is also refreshed by the 200 OK responses being periodically originated from a signalling gateway. An external device in infrastructure networks can register its address into a signalling gateway by using a REGISTER message because the signalling gateway embeds the function of a SIP registrar. By interworking signalling for services with infrastructure networks through the signalling gateway, it is possible to establish a service session between any device in a smart zone and an external device in infrastructure networks.

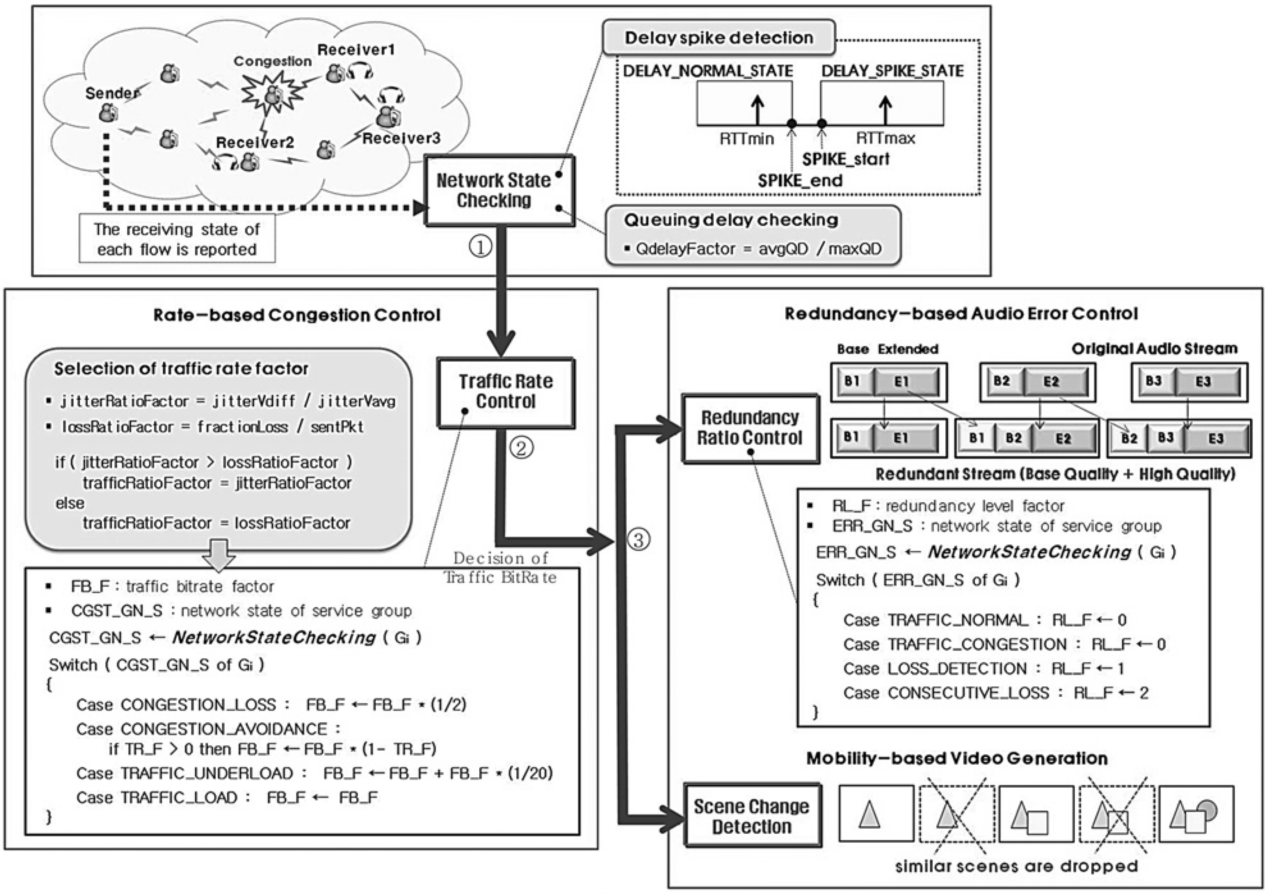
As described in Fig. 2*b*, any device in a smart zone becomes a service initiator by sending a SETUP_GROUP or INVITE message for creating a group-based or peer-to-peer service. For group-based service, the service information related to the creation, destruction and change of a service group is exchanged between a service initiator and a smart zone manager through SETUP_GROUP, RESET_GROUP and RELEASE_GROUP messages. When receiving SETUP_GROUP, RESET_GROUP and RELEASE_GROUP messages from a service initiator, a smart zone manager broadcasts a ZONE_INFO message including changed information to other devices in a smart zone in order to inform the changed service information. When leaving or joining in a service group, a device requests a service withdrawal or subscription by sending a JOIN_GROUP/LEAVE_GROUP message to a service initiator described in the group-ID header field of a ZONE_INFO message.

When communicating with a destination device, smart devices look up the information of binding address at their local cache. In case of no proper binding, they forward their request message to a SIP proxy module of the signalling gateway or smart zone router by judging that a destination device is not located in a current smart zone. If there is binding information in the local cache, the devices send the packet of request message to their smart zone manager to forward to a destination device inside a smart zone. In this way, by applying mechanisms to distribute the functions of SIP servers among devices in *ad-hoc* networks, our proposed platform gives the features of discovering mobile devices and establishing SIP-based service sessions with them, while keeping interoperability with standard SIP applications.

3.2 QoS-aware transmission scheme for the delivery of service contents

The congestion in mobile *ad-hoc* networks affects the whole area of networks because multiple sending devices compete for available bandwidth over a shared communication medium. The mobile *ad-hoc* networks suffer from the transmission losses caused by link error in addition to congestion leading to poor performance for convergence services. If losses from link error are misinterpreted as congestion loss in wireless network environments where non-congestion loss occurs frequently, the quality of convergence services is severely degraded from their incorrect operation. Therefore convergence services in mobile *ad-hoc* networks require the mechanisms to enhance QoS performance by applying proper algorithms to discriminate the cause of packet loss. The efficient method to enhance the QoS performance of multimedia traffic in dynamic networking service is to adjust data transmission rate according to a current network state while considering unique data traffic characteristics. The factors of packet loss and packet arrival delay on receiving devices as well as the high traffic amount of generated multimedia data are currently the big obstacle in the realisation of multimedia conferencing or convergence service since sources of most traffic are video and audio.

The QoS-aware transmission scheme of the proposed platform focuses on the end-to-end algorithms to react on the differentiated wireless losses by using the loss differentiation algorithm distinguishing between congestion loss and link error loss. If the traffic congestion occurs, the link breakage or change of routing paths happens frequently, and the delay of packet transmission or queuing is consequently increased. Therefore QoS-aware transmission scheme performs the function of rate-based congestion control which avoids network congestion by controlling the sending traffic rate depending on variations in the queuing and end-to-end transmission delay. With this function, it can cope with incipient congestion before congestion loss occurs, and can also prevent network collapse arising from frequent traffic congestion. When the traditional algorithm retransmitting lost packets for reliable data transmission in mobile *ad-hoc* networks is applied, the packet delay and jitter are increased and then eventually the QoS for real-time traffic becomes worse [23]. For this reason, the QoS-aware transmission scheme supports the functions of redundancy-based audio error control and mobility-based video generation as efficient methods for the reliable data transmission in dynamic networking environments.



```
▪ QdelayFactor = avgQD / maxQD
```

```
▪ jitterRatioFactor = jitterVdiff / jitterVavg
▪ lossRatioFactor = fractionLoss / sentPkt

if ( jitterRatioFactor > lossRatioFactor )
    trafficRatioFactor = jitterRatioFactor
else
    trafficRatioFactor = lossRatioFactor
```

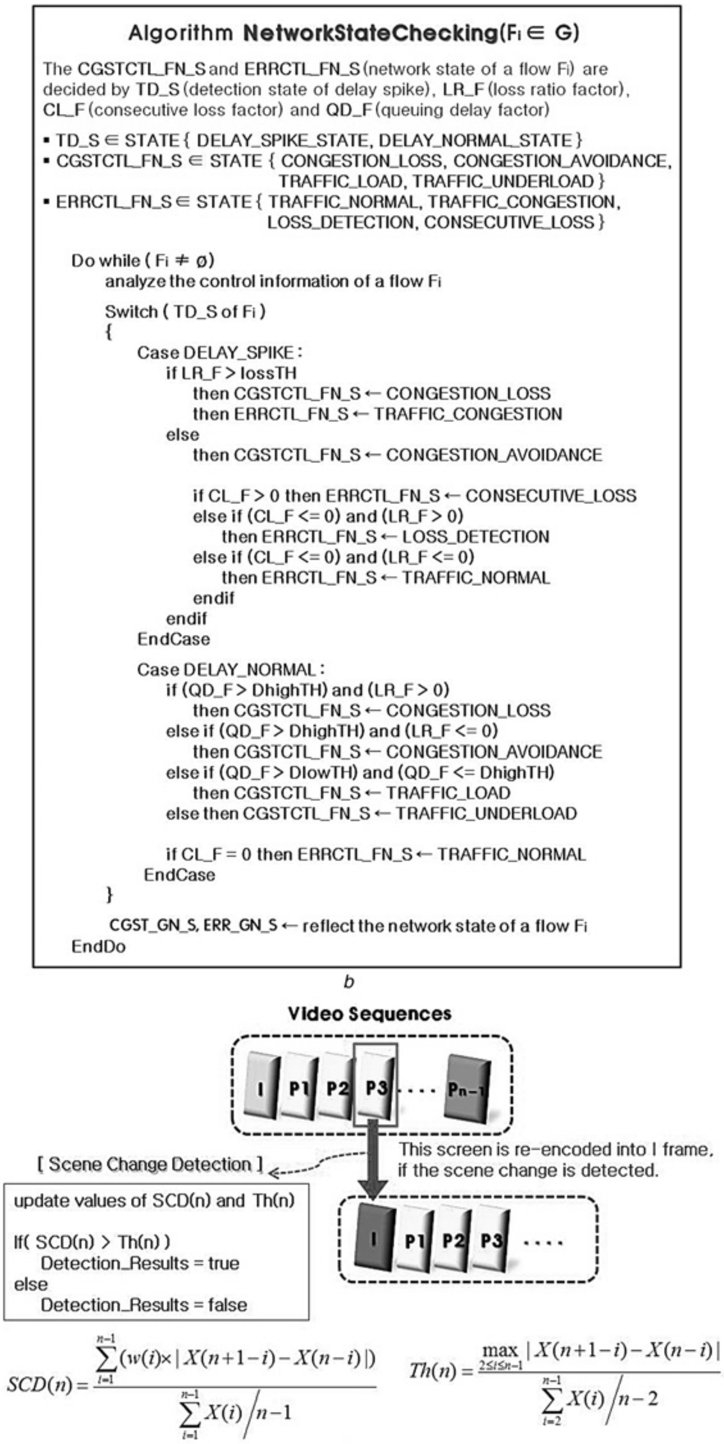
```
▪ FB_F : traffic bitrate factor
▪ CGST_GN_S : network state of service group
CGST_GN_S ← NetworkStateChecking ( Gi )
Switch ( CGST_GN_S of Gi )
{
    Case CONGESTION_LOSS :  FB_F ← FB_F * (1/2)
    Case CONGESTION_AVOIDANCE :
        if TR_F > 0 then FB_F ← FB_F * (1- TR_F)
    Case TRAFFIC_UNDERLOAD :  FB_F ← FB_F + FB_F * (1/20)
    Case TRAFFIC_LOAD :  FB_F ← FB_F
}
```

```
▪ RL_F : redundancy level factor
▪ ERR_GN_S : network state of service group
ERR_GN_S ← NetworkStateChecking ( Gi )
Switch ( ERR_GN_S of Gi )
{
    Case TRAFFIC_NORMAL :  RL_F ← 0
    Case TRAFFIC_CONGESTION :  RL_F ← 0
    Case LOSS_DETECTION :  RL_F ← 1
    Case CONSECUTIVE_LOSS :  RL_F ← 2
}
```

a

Fig. 3 *Smart contents delivery mechanism in service-oriented networking platform*

a Main algorithm of QoS-aware transmission scheme
b Detailed algorithm of network state checking
c Detailed algorithm of mobility-based video generation



```
Algorithm NetworkStateChecking(Fi ∈ G)
The CGSTCTL_FN_S and ERRCTL_FN_S (network state of a flow Fi) are
decided by TD_S (detection state of delay spike), LR_F (loss ratio factor),
CL_F (consecutive loss factor) and QD_F (queuing delay factor)
▪ TD_S ∈ STATE { DELAY_SPIKE_STATE, DELAY_NORMAL_STATE }
▪ CGSTCTL_FN_S ∈ STATE { CONGESTION_LOSS, CONGESTION_AVOIDANCE,
                         TRAFFIC_LOAD, TRAFFIC_UNDERLOAD }
▪ ERRCTL_FN_S ∈ STATE { TRAFFIC_NORMAL, TRAFFIC_CONGESTION,
                        LOSS_DETECTION, CONSECUTIVE_LOSS }

  Do while ( Fi ≠ ø)
      analyze the control information of a flow Fi
      Switch ( TD_S of Fi )
      {
          Case DELAY_SPIKE :
              if LR_F > lossTH
                  then CGSTCTL_FN_S ← CONGESTION_LOSS
                  then ERRCTL_FN_S ← TRAFFIC_CONGESTION
              else
                  then CGSTCTL_FN_S ← CONGESTION_AVOIDANCE

                  if CL_F > 0 then ERRCTL_FN_S ← CONSECUTIVE_LOSS
                  else if (CL_F <= 0) and (LR_F > 0)
                      then ERRCTL_FN_S ← LOSS_DETECTION
                  else if (CL_F <= 0) and (LR_F <= 0)
                      then ERRCTL_FN_S ← TRAFFIC_NORMAL
                  endif
              endif
          EndCase

          Case DELAY_NORMAL :
              if (QD_F > DhighTH) and (LR_F > 0)
                  then CGSTCTL_FN_S ← CONGESTION_LOSS
              else if (QD_F > DhighTH) and (LR_F <= 0)
                  then CGSTCTL_FN_S ← CONGESTION_AVOIDANCE
              else if (QD_F > DlowTH) and (QD_F <= DhighTH)
                  then CGSTCTL_FN_S ← TRAFFIC_LOAD
              else then CGSTCTL_FN_S ← TRAFFIC_UNDERLOAD

              if CL_F = 0 then ERRCTL_FN_S ← TRAFFIC_NORMAL
           EndCase
      }
      CGST_GN_S, ERR_GN_S ← reflect the network state of a flow Fi
  EndDo
```

b

```
update values of SCD(n) and Th(n)

If( SCD(n) > Th(n) )
    Detection_Results = true
else
    Detection_Results = false
```

$$SCD(n) = \frac{\sum_{i=1}^{n-1}(w(i)\times|X(n+1-i)-X(n-i)|)}{\sum_{i=1}^{n-1}X(i)\Big/n-1} \qquad Th(n) = \frac{\max_{2\le i\le n-1}|X(n+1-i)-X(n-i)|}{\sum_{i=2}^{n-1}X(i)\Big/n-2}$$

c

Fig. 3 *Continued*

The proposed scheme can reduce packet losses and improve the QoS through the function of redundancy-based audio error control that adjusts the number of piggybacked redundant audio blocks depending on variations in the end-to-end transmission delay and the burst loss rate. Furthermore, the mechanisms of mobility-based video generation enables the efficient usage of wireless bandwidth by applying a method of video encoding based on scene change detection (SCD) so as to generate the minimal traffic.

As shown in Fig. 3, after analysing the received control information whenever receiving a control packet periodically, our proposed scheme determines the states of current network (CGSTCTL_FN_S, ERRCTL_FN_S) by applying four factors (end-to-end transmission delay, queuing delay, packet loss rate and consecutive loss rate) as the signal for congestion loss and burst loss. When predicting the delay spike phenomenon, it makes use of the round trip time factor to identify the state of transmission paths to the receivers from the sender (DELAY_SPIKE_STATE, DELAY_NOR MAL_STATE) by comparing with two thresholds (Bspike_start, Bspike_end). If packet loss occurs in the DELAY_SPIKE_STATE or both packet loss and high queuing delay are detected in the DELAY_NORMAL_STATE, then the state of current network (CGSTCTL_FN_S) becomes the CONGESTION_LOSS_STATE. In this case, the detected loss is judged as congestion loss and then the amount of sending traffics is reduced by the multiplicative decreasing rate by the proposed scheme. If the state of current network (CGSTCTL_FN_S) is decided to be the CONGESTION_AVOIDANCE _STATE, the sending traffic is decreased by the decreasing rate of packet loss or jitter difference ratio, and it is increased by the linear increasing rate in the case of TRAFFIC_UNLOAD_STATE. As shown in the algorithm flow of Fig. 3, our congestion control mechanism can prevent the reduction of network throughput by classifying the loss depending on the state of current network (CONGESTION_LOSS_STATE, CONGESTION_AVOIDANCE_ STATE, TRAFFIC_LOAD_STATE, TRAFFIC_UNLOAD _STATE) and adjusting the amount of sending traffic according to the differentiated loss.

If the redundant audio data is piggybacked into the payload of a next packet and then is transmitted together as one packet, the missed audio data can be reconstructed from redundant data of a next packet arrived at a receiving device. Even if burst packet losses occur, our platform can recover the multiple consecutive losses by increasing the number of redundant blocks added to each packet, and thus improve the quality of audio. However, there is limitation on the desirable packet size in the audio stream for the available maximum bandwidth. Our error control mechanism can reconstruct the missed audio data by controlling a redundancy ratio under the maximum allowed network resource dynamically according to the network state (TRAFFIC_NORMAL_STATE, TRAFFIC_CONGESTION_STATE, LOSS_DETECTION_STATE, CONSECUTIVE_LOSS_STATE).

In addition to the efficient traffic transmission mechanisms, our platform requires a video generation mechanism based on the

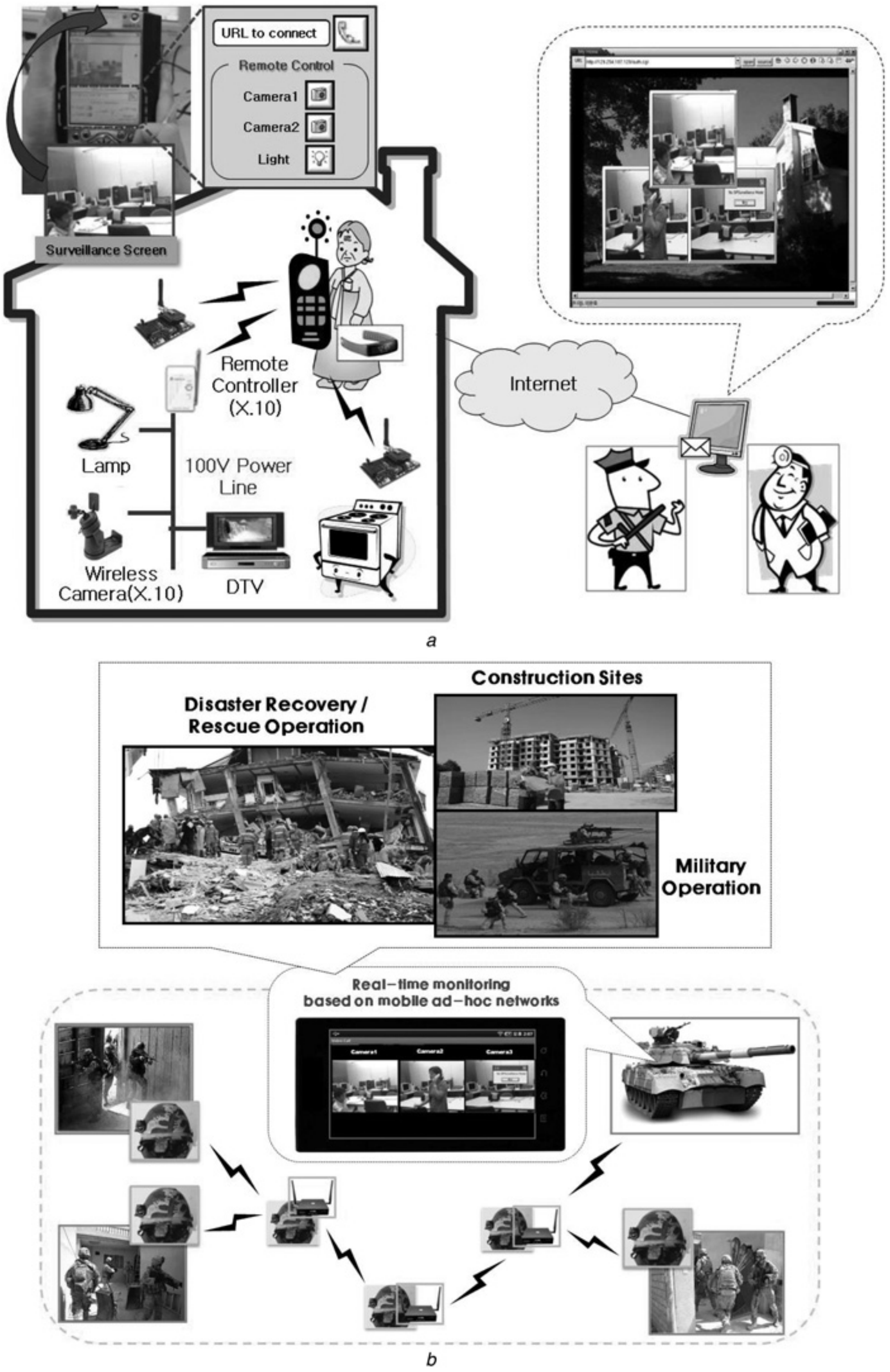


Fig. 4 *Screenshots of convergence services based on implemented platform prototype*

a Ubiquitous surveillance and control service
b Remote monitoring service over mobile *ad-hoc* networks

detection algorithm for scene change so as to produce only minimal video sequences. This detection algorithm takes advantage of the difference in the amount of encoded bits between a current frame and previous frames as an indicator to detect a scene with moving objects or an entire changed scene by comparing with previous frames. As described in Fig. 3*c*, our detection algorithm evaluates the value of SCD factor, by calculating the ratio of the weighted difference value to the average value in the amount of the encoded bit-stream of previous frames, where $w(i)$ is a weighting factor for the difference value of the encoded bit-stream between current frame $X(n+1-i)$ and previous frame $X(n-i)$, and it has a lower value as the i value increases. Since the threshold has great influences on the detection results of scene change, it should be applied dynamically depending on the type of video data, as shown in Fig. 3*c*. If the measured value of SCD factor is greater than the threshold value, the corresponding frame is recognised as the changed scene. In this case, our video generation mechanism generates I frame again from the corresponding scene and then transmits the encoded bit-stream of this I frame. Otherwise, the other frames that have not been recognised as changed scenes are decided as the similar scenes, and in turn, discarded. Therefore our video generation mechanism can reduce the generation traffic by discarding the frames of similar scenes and provide a high quality of media data by reproducing I frames of changed scenes.

4 Implementation and experimental results of the proof-of-concept prototype

This section will show the screenshots of convergence services offered in a developed platform prototype. We carried out experiments in multi-hop wireless network environments and proved the efficiency of QoS-aware transmission scheme through the testing of a developed platform prototype.

4.1 Prototype development for the proof-of-concept

In order to demonstrate the feasibility of the proposed platform, this paper developed the proof-of-concept prototype which provides convergence services of the following sub-scenarios. Fig. 4*a* presents a snapshot of the ubiquitous surveillance and control service that uses the X.10 RF wireless cameras and a home server. The scenario of this service illustrated in Fig. 4*a* shows that the proposed platform enables to interwork with an existing SIP service in infrastructure networks. In order to support senior citizens who live alone, the user of this service (police or doctor) can request the session of surveillance service with the mobile device or his office PC and can view the inner status of house. If his work environment is moved, he can request the transfer operation of an on-going surveillance session into the most nearest device by acquiring information for his surrounding display devices. In addition, he can remotely turn on or off the related appliances by exchanging control messages in case of the emergency such as fire accident. When the structure of this service is expanded, we can control connected devices in various smart environments such as home automation, industrial automation and light control system, and can also monitor the status or electric power consumption of appliances.

Fig. 4*b* illustrates a screenshot of the real-time monitoring service for combat operations in battlefields where no network infrastructures are available. This service presents the possibility to dynamically build a real-time monitoring system by forming a service group in the form of smart zone in a mobile *ad-hoc* network environment. In the scenario of Fig. 4*b*, this service can

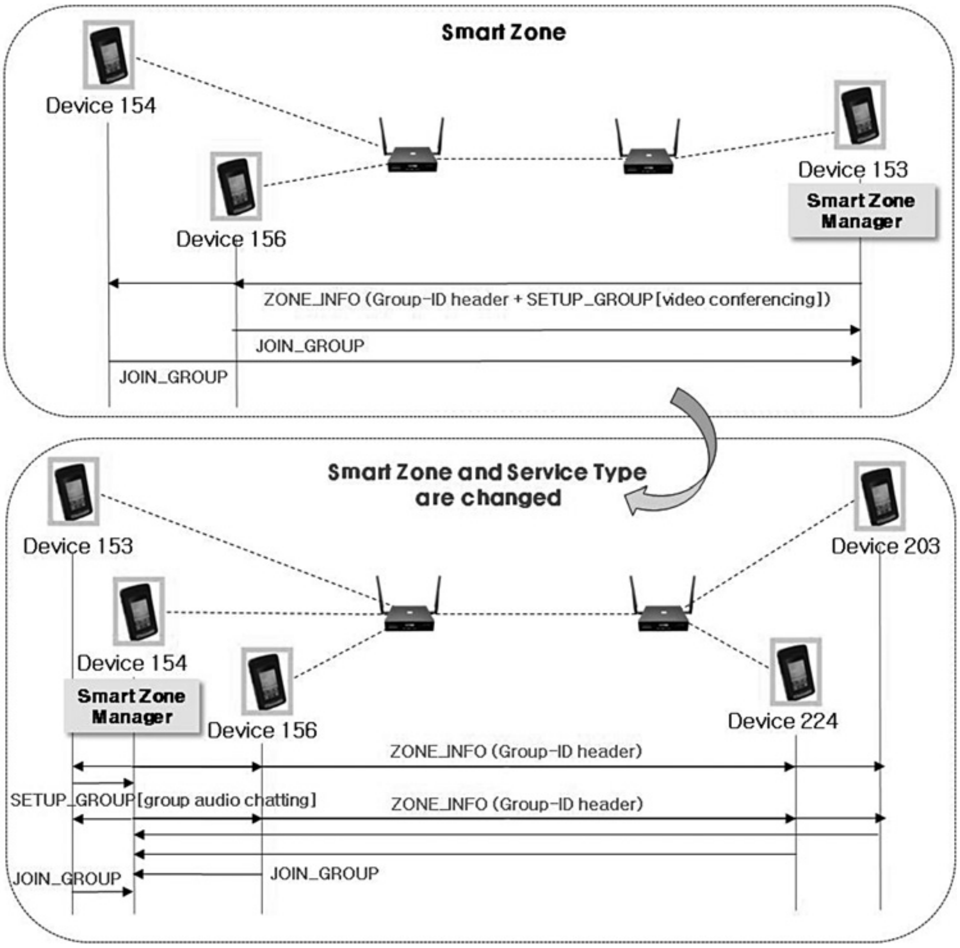


Fig. 5 *Experimental environments and test scenarios of smart zone-based services*

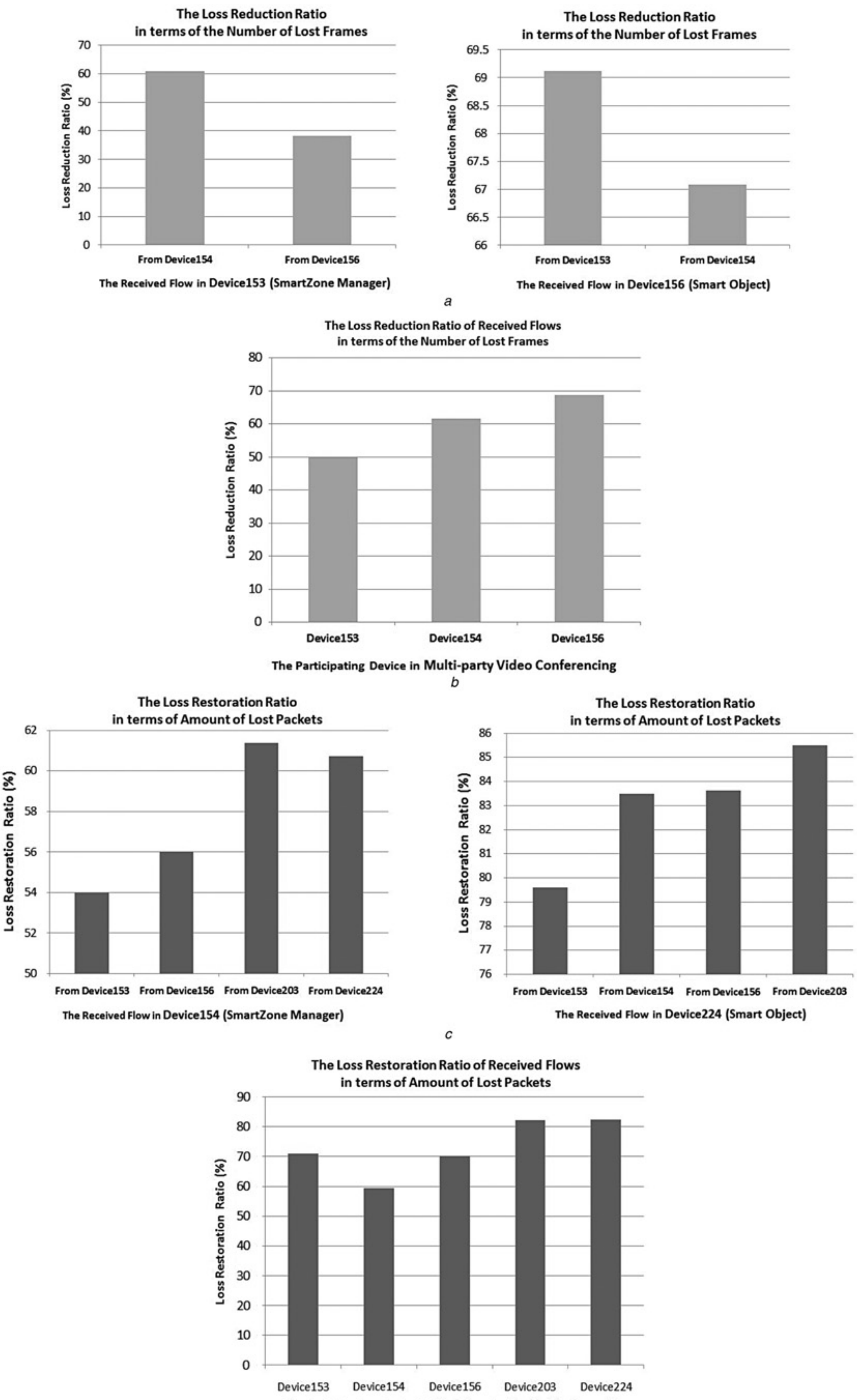


Fig. 6 *Experimental results of smart zone-based services in service-oriented networking platform*

a Loss reduction ratio on the SmartZone Manager and smart object in the smart zone for multi-party video conferencing
b Execution results of congestion control algorithm in multi-party video conferencing
c Loss restoration ratio on the SmartZone Manager and smart object in the smart zone for multi-party audio conferencing
d Execution results of error control algorithm in multi-party audio conferencing

notify the monitoring situations so as to support co-operations in construction site and rescue operations in disaster area, in addition to the combat operations in battlefields. Furthermore, it is possible to remotely monitor the situation by using unmanned robots equipped with a camera in dangerous places where people cannot enter.

4.2 Performance evaluation of the developed platform prototype

This paper presents the performance results of the proposed platform providing smart zone-based group services by test experiments. To evaluate the performance of the proposed platform, the developed platform prototype was executed according to the test scenarios for smart zone-based group services in the multi-hop group communication environment where the network topology is described in Fig. 5. The performance of QoS-aware transmission scheme is measured while the service of multi-party video conferencing is proceeding in a smart zone formed by the SmartZone Manager (device 153) on the proposed platform. Later, a smart zone and the type of service are changed by releasing a service session for multi-party video conferencing and forming another smart zone managed by the SmartZone Manager (device 154). The performance of this scheme is measured again during the service of multi-party audio conferencing provided in another smart zone. The QoS-aware transmission scheme was applied in a specific time in order to analyse prior and posterior execution results of the algorithms in this scheme during the experiments of the multi-party video and audio conferencing.

While three mobile devices are transmitting H.264 encoded stream of the QVGA resolution in the test scenario of multi-party video conferencing, the number of lost frames in the received flows was measured on each device, and then these measured results are depicted into the graphs in Figs. 6*a* and *b*. The result graphs in Figs. 6*a* and *b* show the loss reduction ratio in terms of the number of lost frames derived from prior and posterior execution results of congestion control algorithm. In this experiment, the sending rate of video stream was set to 400 kbps and the frame rate of H.264 encoder was configured to 15 fps. From the experimental results of Fig. 6*b*, the loss of received flows on each device was reduced by about half in comparison with the experiment result applying no congestion control mechanism. This experimental result proves the efficiency of rate-based congestion control algorithm showing improved performance in terms of the number of lost frames.

Figs. 6*c* and *d* depict the graphs of the measured experimental results in terms of amount of lost packets in multi-party audio conferencing using the G.729.1 codec set to 16 kHz sampling frequency. The result graphs in Figs. 6*c* and *d* show the loss restoration ratio in terms of amount of lost packets derived from prior and posterior execution results of error control algorithm. In these graphs, the redundancy-based audio error control algorithm restored ∼60% from the congestion in terms of amount of lost packets. However, if the available bandwidth is severely lowered because of the continuous traffic congestion, the restoration rate of lost packets will be reduced by the performance limitations of our algorithm.

From the experimental results of Figs. 6*a–d*, the loss of received flows on the SmartZone Managers (device 153 and device 154) is higher than the one on the other devices (smart objects) within the same smart zone for multi-party video and audio conferencing, when the loss caused from the multi-hop communication is considered. These experimental results show that the SmartZone Manager has greater loss than the other devices because of the control overhead for managing a smart zone.

The experiment of mobility-based video generation algorithm was performed in the video streaming environment which consists of embedded devices supporting the hardware accelerator function to encode or decode the video frames compressed in H.264. In the

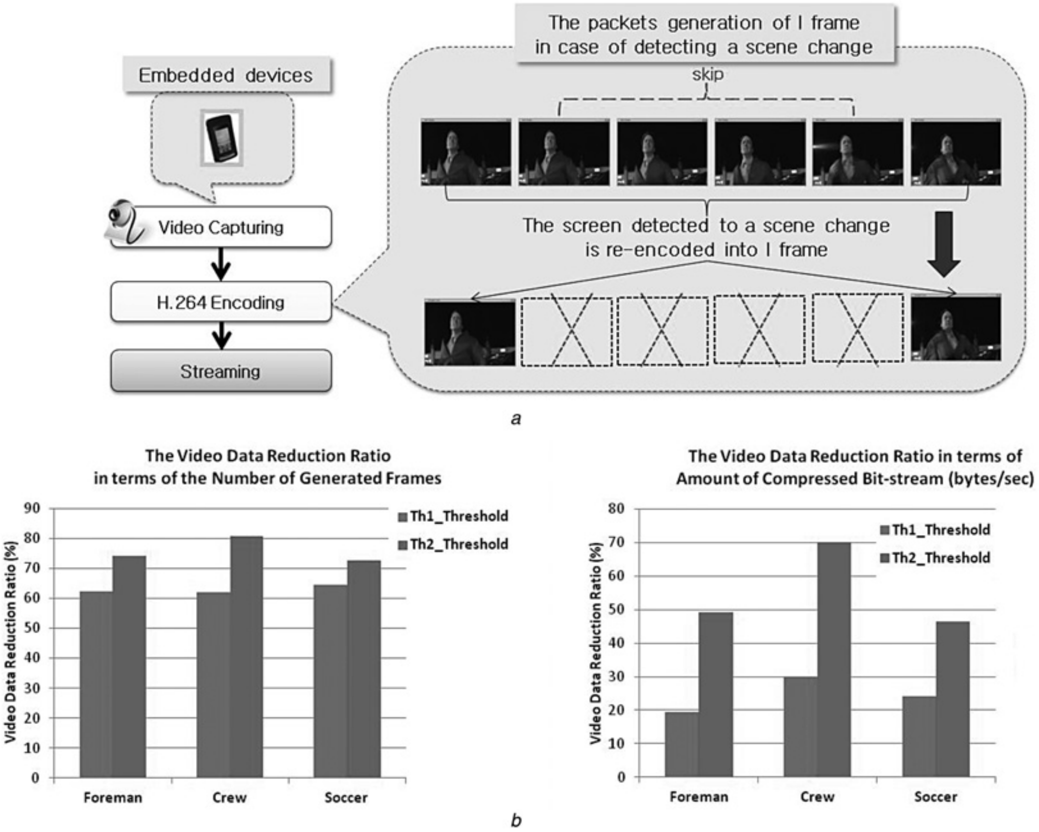


Fig. 7 *Experimental results of mobility-based video generation*

a Test experiment for the detection algorithm of scene change

b Experimental results of video generation based on the detection algorithm of scene change experiment for detection algorithm of scene change with the H.264 hardware codec in the Android platform, our algorithm reproduces video frames detected as the scene change into I frames, and then transmits the encoded video data to destination devices. In addition, during this experiment, the video frames recognised as the similar scene are discarded as depicted in Fig. 7*a*.

We repeated the experiment in Fig. 7*a* with various contents (foreman, crew and soccer videos), and measured the number of generated media frames and the average amount of generated media data per second. From these measured results, the result graph in Fig. 7*b* depicts the video data reduction ratio of video frames generated by the mobility-based video generation algorithm to original video sequences in terms of the number of generated frames and amount of compressed bit-stream. Depending on the type of test video and the value of applied threshold, the video data reduction ratio in terms of the number of generated frames and amount of compressed bit-stream becomes different, as shown in Fig. 7*b*. In the right graph of Fig. 7*b*, the ratio in terms of amount of compressed bit-stream is about 20 and 45%, respectively, when our algorithm selected the thresholds of Th1 (0.5) and Th2(1.0). From the above results, it is inferred that our algorithm enables mobile embedded devices to access the network bandwidth effectively and increases the throughput of packet transmission, by minimising the amount of bit-stream generated at the video encoder.

5 Conclusions

This paper has mentioned the importance of the service-oriented networking platform in the era of pervasive computing and M2M technologies. The distinctive design of service-oriented networking platform was presented to provide dynamic smart services seamlessly. This platform enhances the scalability and availability of convergence services in wireless network environments by suggesting the structure of service overlay network based on multiple smart zones. The smart delivery scheme in our platform also guarantees the QoSs and provides seamless services for end users in heterogeneous network environments. It uses the SIP protocol for end-to-end interoperable signalling with existing systems in an infrastructure.

The proof-of-concept prototype for our platform demonstrated the feasibility of various additional services by the realisation of two representative services, ubiquitous surveillance/control service and remote monitoring service over the mobile *ad-hoc* network. In addition, this paper has focused on evaluating the performance of smart delivery scheme in our platform. For seamless service provision over heterogeneous networks, the QoS-aware transmission scheme was proposed: rate-based congestion control, redundancy-based audio error control and mobility-based video generation.

The performance of the suggested algorithms was evaluated in multi-hop wireless network environments. When applying the rate-based congestion control algorithm, the loss of received flows was reduced by about half in comparison with the experiment result using no congestion control mechanism. Secondly, the redundancy-based audio error control algorithm restored ∼60% from the congestion in terms of amount of the lost packets. Thirdly, the mobility-based video generation algorithm reduced the amount of compressed bit-stream by about 20 and 45%, respectively, when two different thresholds values were used. Based on the above experimental results, it is shown that our QoS-aware transmission scheme in the proposed platform is very efficient.

The proposed platform can also support a similar service such as SIP video call or SIP collaboration service that works with a service server in the IMS platform. On the contrary, the IP multimedia subsystem (IMS) platform can provide services on the proposed platform only if service infrastructure is constructed with the support of the extended signal, proxy server and media processing server for those services. Therefore it has the limitation in service provision in contrast with the proposed platform supporting service-oriented networking where service network can be dynamically constructed by the smart devices.

For the future work, load balancing and security issues should be considered in order to complete the platform architecture. One important security issue is how to guarantee mutual authentication of users and manage the credential keys for security in non-infrastructure environments where it is difficult to share the changed distributed group key because of frequent packet loss.

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