UNIVERSITI PUTRA MALAYSIA

ADAPTIVE ERROR CONTROL SCHEMES FOR SUPPORTING QUALITY OF SERVICE IN WIRELESS ATM NETWORKS

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This Thesis is Dedicated to My

Husband

MD. MOSLEMUDDIN FAKIR

Daughter

NUSRAT JAHAN SHOUMY

&

Parents

MOZAMMEL HAQUE, KOHINOOR BEGUM, FATIMA BEGUM

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy.

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Chairman: **Professor Borhanuddin Bin Mohd Ali, Ph.D.**

Faculty: **Engineering**

This thesis deals with the error control problems, which is one of the major issues for supporting quality of service (QoS) in wireless ATM (WATM). Generally in wireless communication, error is induced by impairment prone wireless links. As a method of quality of service based error control, the design and performance evaluation of a retransmission based error control scheme is proposed to overcome wireless channel impairments for multimedia traffic support over wireless ATM networks. The purpose of the proposed error control scheme is to provide error-free services to the higher layers by either correcting the errors in a packet or recovering corrupted packets by retransmission in a wireless link.

From the perspective of error control, multimedia traffic can be divided into two types: loss-sensitive traffic and delay-sensitive traffic. To support all these traffic over WATM networks, we propose two approaches for error control. One approach is to utilize the reliable AAL protocol, which are referd to as AALX1 and

AALX2, as the end-to-end error control, based on our knowledge-based selective-reject automatic repeat request (KSRARQ) scheme, and adaptive header protection with KSRARQ scheme for loss-sensitive and delay-sensitive traffic, respectively. The novel KSRARQ is based on selective-reject ARQ (SRARQ) scheme with variable packet size, periodic channel status message transmission for loss-sensitive traffic and periodic channel status check (and only transmit a status message if a lost or errored packet is detected) for delay-sensitive traffic. The packet size varies with the channel condition, maximizing the throughput efficiency. The channel status messages are sent or checked periodically by the receiver to avoid redundant retransmissions by obsoleting the timeout mechanism and reducing the overhead due to frequent control packet transmission. As adaptive header protection for UDP/IP packet header, which contains the most important information, host address and port number for packet delivery, AALX2, uses an adaptive Reed-Solomon (RS) code set with correcting capability t = 1 to 4 bytes, which adapts with the channel bit error rate (BER) for reliable packet delivery and optimize the bandwidth efficiency for the respective connection.

At the link-level, a data-link hybrid adaptive error control scheme (HAECS) combining KSRARQ with an adaptive set of Bose-Chaudhuri-Hocquenghem (BCH) codes as the forward error correction (FEC) is proposed. The key ideas of this scheme are to adapt the packet length and code rate to the channel conditions using incremental redundancy, maximizing the throughput efficiency.

For delay-sensitive traffic, the retransmission procedure is constrained to complete within a specified recovery time interval defined at call setup time, the end-to-end

quality is controlled by the higher layers and not to discard any packet at lower layers (AAL or data link layer). For each wireless link, the HAECS is used as the link-level error control to raise the BER performance from its raw level to a level acceptable to higher layer protocols. The benefit of our HAECS is its flexibility to adapt to different ATM services or any other wireless services with varying QoS requirements. The analytical and simulation results show the efficiency of our error control schemes.

Abstrak tesis dipersembahkan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk ijazah Doktor Falsafah.

SKIM-SKIM PENGAWALAN RALAT MUDAH SUAI UNTUK MENYOKONG KUALITI SERVIS DI DALAM RANGKAIAN-RANGKAIAN ATM WAYARLES

Oleh

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April 2003

Pengerusi: **Professor Borhanuddin Bin Mohd Ali, Ph.D.**

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Tesis ini adalah mengenai masalah kawalan ralat, yang menjadi satu isu besar untuk menyokong kualiti servis (QoS) di dalam ATM wayarles (WATM). Secara umumnya di dalam komunikasi wayarles, ralat diaruh oleh kecenderungan kejejasan pautan-pautan wayarles. Sebagai satu kaedah pengawalan ralat berasaskan kualiti servis, rekabentuk dan penilaian prestasi satu skim pengawalan ralat berasaskan penghantaran semula dicadangkan untuk menyelesaikan kejejasan saluran wayarles dalam sokongan trafik multimedia menerusi pautan ATM wayarles. Tujuan skim pengawalan ralat cadangan ini adalah untuk menyediakan servis yang bebas ralat kepada lapisan-lapisan lebih tinggi samada melalui pembetulan ralat di dalam satu-satu paket atau pemulihan paket-paket yang rosak dengan penghantaran semula di dalam pautan wayarles.

Dari perspektif kawalan ralat, trafik multimedia boleh dibahagikan kepada dua jenis: trafik peka-kehilangan dan trafik peka-kelengahan. Untuk menyokong semua jenis trafik ini menerusi pautan WATM, kami mencadangkan dua pendekatan untuk mengawal ralat. Satu pendekatan adalah dengan menggunakan protokol AAL boleh harap, yang dirujuk sebagai AALX1 dan AALX2, sebagai kawalan ralat hujung ke hujung, berasaskan skim pohon ulang automatik tolakan-memilih berasaskan pengetahuan (KSRARQ), dan satu lagi adalah perlindungan kepala mudah suai dengan skim KSRARQ untuk trafik peka-kehilangan dan peka-kelengahan. Keunikan KSRARQ adalah berasaskan skim ARQ tolakan-memilih (SRARQ) dengan saiz paket yang pelbagai, penghantaran mesej status saluran untuk trafik peka-kehilangan dan pemeriksaan status saluran berkala (dan hanya menghantar satu mesej status jika ada kehilangan atau paket teralat dikesan) untuk trafik peka-kelengahan. Saiz paket beragam dengan keadaan saluran, sekaligus memaksimakan kecekapan truput. Mesej-mesej status saluran dihantar atau diperiksa secara berkala oleh penerima untuk mencegah penghantaran semula membazir dengan menarik balik mekanisma tamat masa dan mengurangkan overhed disebabkan penghantaran paket yang kerap. Sebagai perlindungan kepala mudah suai untuk kepala paket UDP/IP, yang mengandungi maklumat terpenting, alamat hos dan nombor port untuk penghantaran paket, AALX2 menggunakan set kod Reed-Solomon (RS) mudah suai dengan keupayaan pembetulan t = 1 ke 4 byte, yang disesuaikan dengan kadar ralat bit saluran untuk penghantaran paket yang dipercayai dan mengoptimum kecekapan lebarjalur untuk sambungan tersebut.

Pada peringkat pautan, satu pautan-data skim pengawalan ralat mudah suai hybrid (HAECS) menggabungkan KSRARQ dengan satu set kod Bose-Chaudhuri-Hocquenghem (BCH) mudah suai semasa pembetulan ralat depan dicadangkan. Idea utama skim ini adalah untuk menyesuaikan panjang paket dan kadar kod dengan keadaan saluran menggunakan lebihan meningkat, sekaligus memaksimakan kecekapan truput.

Untuk trafik peka-kelengahan, prosedur penghantaran semula dikekang untuk siap dalam jangka masa pemulihan tertentu yang ditetapkan pada masa persediaan panggilan, kualiti hujung ke hujung dikawal oleh lapisan-lapisan lebih tinggi dan dicegah membuang sebarang paket pada lapisan-lapisan lebih rendah (AAL atau lapisan pautan data). Untuk setiap pautan wayarles, HAECS digunakan sebagai pengawal ralat aras-pautan untuk meningkatkan prestasi BER dari aras asal kepada aras yang boleh diterima oleh protokol lapisan yang lebih tinggi. Kelebihan HAECS kami adalah kelenturannya untuk menyesuaikan diri dengan servis ATM yang berbeza atau sebarang servis wayarles yang lain dengan keperluan QoS yang beragam. Keputusan-keputusan analisis dan simulasi menunjukkan kecekapan skim-skim pengawalan ralat kami.

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ABBREVIATIONS

AAL	ATM Adaptation Layer
AAU	ATM User to ATM User
ABR	Available Bit Rate
ACK	Acknowledgement
ACR	Allowed Cell Rate
AFEC	Adaptive Forward Error Correction
AP	Access Point
ARQ	Automatic Repeat Request
ASIC	Application Specific Integrated Circuits
AT	Arrival Time
ATM	Asynchronous Transfer Mode
AWGN	Additive White Gaussian Noise
BCH	Bose-Chaudhuri-Hocquenghem
BER	Bit Error Rate
BISDN	Broadband Integrated Service Digital Network
BPSK	Binary Phase Shift Keying
BS	Base Station
BSC	Binary Symmetric Channel
Btag	Beginning of Tag
CAI	Channel Activity Indicator
CBR	Continuous Bit Rate
CCR	Current Cell Rate
CD	Cell Delineation
CDV	Cell Delay Variation
CER	Cell Error Rate
CLP	Probability of Cell Loss
CLR	Cell Loss Ratio
CMR	Cell Misinsertion Rate
CMSN	Continuous Maximum Sequence Number
CNT	Packet Counter
CPCS	Common Part Convergence Sublayer
CPSAR	Common Part Segmentation and Reassembly

CPSRARQ	Common Part Selective Reject Automatic Repeat Request
CRC	Cyclic Redundancy Check
CS	Convergence Sublayer
CSN	Cell Sequence Number
CSU	Control and Switching Unit
CTD	Cell Transfer Delay
DB	Database
DLC	Data Link Control
DQPSK	Differential Quadrature Phase Shift Keying
DQRUMA	Distributed-Queuing Request Update Multiple Access
DRFC	Dynamic Rate-based Flow Control
EAECS	End-to End Adaptive Error Control Scheme
ECS	Error Control Scheme
EFCI	Explicit Forward Congestion Indication
EOT	End of Text
ER	Explicit Rate
ERICA	Explicit Rate Indication for Congestion Avoidance
Etag	End of Tag
FEC	Forward Error Correction
FECI	Forward Error Correction code Indicator
FIFO	First In First Out
FSM	Final State Machine
FT	Fixed Terminals
FTP	File Transfer Protocol
GBN	Go Back N
GF	Galois Field
GSM	Global System for Mobile Communications
HAECS	Hybrid Adaptive Error Control Scheme
HEC	Header Error Control
HER	Header Error Rate
HECS	Hybrid Error Control Scheme
HLP	High Loss Priority
HO	Handoff indicator
HOL	Head of Line