SPECIFICATION OF THE AVC-R-ISA MAC LAYER PROTOCOL

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Abstract

The paper deals with the AVC-R-ISA access protocol, developed in order to maximize the one-step throughput and to solve the hidden stations problems, in a packet radio network cellular structure.

After a brief description of the overall AVC-R-ISA strategy, the actual protocol machine is presented for both kinds of stations (master and slaves) that are presented in the network. A short description of the frame structure is also shown along with a brief discussion about preliminary real world performance results.

1. Introduction

The AVC-R-ISA protocol, proposed and described in [1], represents a strategy for the access rights distribution on a common channel in order to maximize the one-step aggregate throughput. The devised strategy is characterized by its adaptability to channel load variations that may be due to change in radio station density and/or packet generation rate. The presented multi-access protocol refers to a cellular network structure and needs a specialized station, in each cell, referred to in the following as master station or base station, that acts as a synchronization entity and as a feedback and status information disseminator, because of the previously mentioned tasks, the base station is constrained to be placed in a site from which it can directly communicate with any other station in the cell.

In the following, after a brief overview of the overall access strategy, the Medium Access Control Protocol (MACP) and the frame structure for AVC-R-ISA are described. In the last section the complete protocol machine is presented as it was implemented in the 910618 version of the Net/NOS package by Phil Karn.

2. The AVC-R-ISA strategy

The Access Virtual Channel-Radionet-Independent Stations Algorithm is a MAC layer protocol devoted to the solution of the multiple access problem for a packet-switching radio network. Its peculiarity is the capability to adapt to the traffic load variation due to changes both in the number of active stations and in the frame generation rate.

Futhermore, unlike from other MAC layer protocols (e.g. CSMA) the AVC-R-ISA performances are insensitive to the presence of “hidden” stations (i.e., stations that cannot establish one-hop radio links). As already mentioned, the only constraint of this protocol is the need to place the base station in a suitable site, from which it can communicate with any other (slave) station.

The AVC-R-ISA employs an informative centralized data structure (managed by the base station) along with some minor decentralized information.

The slave stations cooperate with the master according to the ISA [2] strategy, for the channel resource assignment. The ISA control rule is applied to a population of slave stations working on a slotted channel.

For each slot we know the channel status information, under the hypothesis that the frame presence in a station buffer is statistically independent of the state of the other slaves and that the station has an unitary frame buffer, so that any frame generated while the buffer is full is discarded.

The goal is to assign the right access to the stations, in order to maximize the one-step throughput and consequently, the probability of no-collision transmission. This is accomplished by uptating a vector p(t) (whose components represent the marginal probability of the presence of the packet in a slave station) on the basis of the stations’ frames generation rate and of the channel feedback reporting one of the following three states : empty slot, collision or successful transmission.

A major problem for a radio slotted network is devising a simple and efficient synchronization mechanism: the AVC-R-ISA achieves this coordinated mechanism by having the base station and the slaves population synchronizing on their respective end-of-carrier (EOC) events [3]. The time interval beetwen two consecutive start-of-carriers by the master will be called “decisional interval” or “generalized slot”. The base station, besides acting as a synchronization entity, provides the broadcasting of feedback along with some global network information, as the slaves are not able, in general, to get this information directly.

The AVC-R-ISA control rule assigns access rights individually, and this requires that the stations possess a local identifier to be assigned upon entering a cell.

The dynamic assignment of local identifiers can be viewed as a “virtual channel number” assignment. The stations that want to enter the network may use a special identifier, say 0, to ask the controller to release an actual identifier.

Thus the identifier number 0 is temporarily common to all users that have not yet been assigned their own channel number.

The incoming stations can generate a connection request by means of an AVC-R-ISA packet devoted to this goal, whenever channel 0 is enabled by the overall ISA algorithm. Obviously, conflict may occur among the stations while using this common identifier, even when channel 0 alone is enabled.

To resolve these conflicts, a controlled Aloha strategy, based on Rivest pseudo-Bayesian broadcast [4], is used. According to the latter, the master estimates the number of incoming stations and tunes channel 0 scheduling rate.

3. The AVC-R-ISA Medium Access Control Protocol (MACP)

The protocol related to the AVC-R-ISA strategy provides a method of establishing, maintaining and terminating the AVC-R-ISA connection. MACP goes through three distinct phases:

1) *Link establishment*

Before, any information may be exchanged, the protocol must first open the connection through an exchange of Connection packets. This exchange is complete, and the Connection state entered, once an Acknowledge Connection packet has been sent from the Master station to the Slave. Any non-AVC-R-ISA link establishment packets received before this change is completed, are discarded.

2) Information exchange

Until a link termination action occours we have a regular information exchange among radio stations according to the AVC-R-ISA strategy.

3) Link termination

The protocol may terminate the link at any time. This usually can be done at the request of a human user or when the. master detects a number of empty slots greater than a fixed threshold, for a given station.

MACP is specified by a number of packet formats and by a protocol machine. We now present an overview of the MACP automation, followed by a representation of the state transition table. As the master and the slave stations perform different tasks they need two different MACP automation.

There are three classes of MACP packets according to the previous mentioned phases:

1) Link establishment packets used to establish a link (e.g., Master/Slave connection request, Master acknowledge connection).

2) Information exchange packets, that encapsulate the upper layer information. The master station not only uses this kind of packets to transmit the upper layer data, but also to broadcast the MAC control

information (e.g., Master synchronization, Slave information). An exception is representated by the “Generation rate updating” packet, sent from the Slave, that comprises only AVC-R-ISA supervisory information.

3) Link termination packets used to terminate a link (e.g., Master/Slave disconnection request, Master acknowledge disconnection, Master rejected connection, Master shutdown).

The protocol machine is defined by events, state transitions and actions. Events include receipt of external commands such as Switch On/Off and Disconnection, expiration of the Connection/Disconnection/Synchronization timers, and receipt of packets. Actions include the starting and restarting of the timers, the transmissions of packets and updates of slave station empty slot counters in order to provide an automatic link termination.

A)

Flag	Protocol Identifier	Feedback	Frame_type	S Address	T Address	Channel

TX-Probability Channel 0	Bit-map length	Access rights (Bit-map)	Information field	FCS

B) D)

Flag	Protocol Identifier	Feedback	Frame_type	S Address	T Address

TX-Probability Channel 0	Bit-map length	Access rights (Bit-map)	Information field	FCS

C)

Flag	Protocol Identifier	Feedback	Frame_type	S Address

TX-Probability Channel 0	Bit-map length	Access rights (Bit-map)	Information field	FCS

E) F)

Flag	Protocol Identifier	Feedback	Frame_type	S Address	Channel

TX-Probability Channel 0	Bit-map length	Access rights (Bit-map)	Information field	FCS

G)

Flag	Protocol Identifier	Feedback	Frame_type	S Address	FCS

Fig. 1 S (Master Station)-FRAMES : A) *T* Connection Acknowledge; B) *T* Connection Request; C) Synchronization; D) *T* Connection Rejected; E) *T* Disconnection Request; F) *T* Disconnection Acnowledge; G) Shutdown (forced disconnection of all the *T* station).

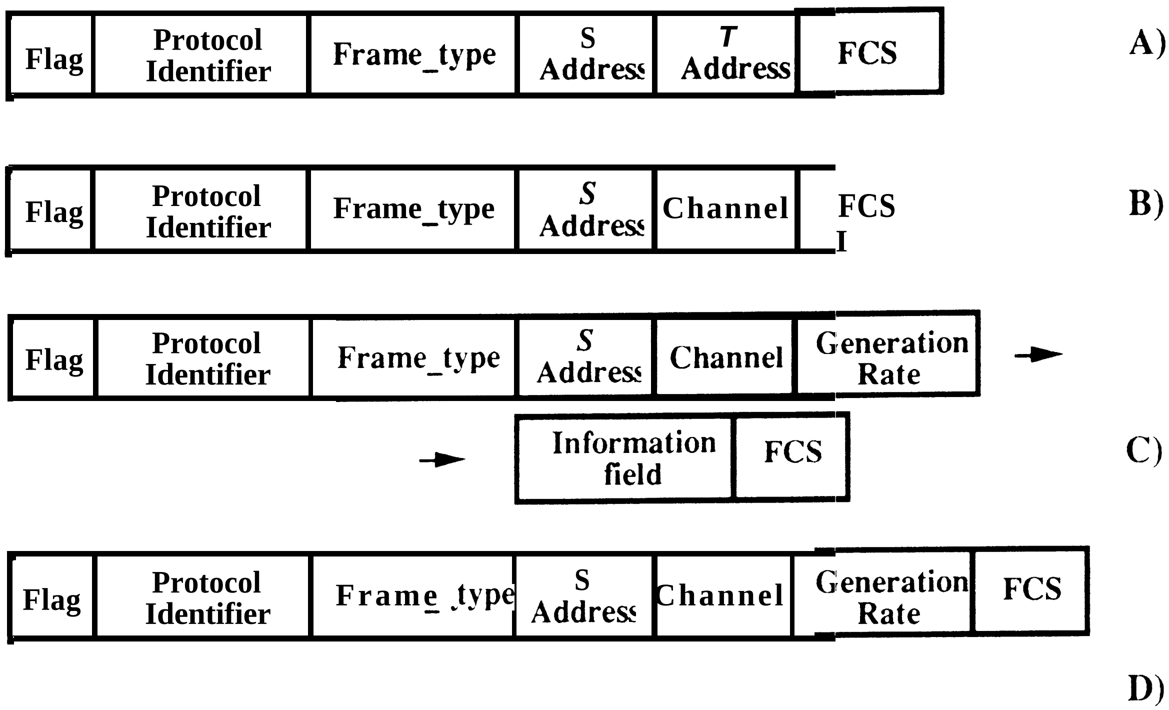

Fig. 2 S (Slave Station)-FRAMES : A) Connection Request; B) Disconnection Request; C) Information; D) Generation Rate Updating.

The complete set of MACP frames is depicted in Figs. 1 and 2 where the Master and Slave stations are indicated as S and T, respectively.

4. State Transition Tables

The complete state transition tables for the Master and the Slaves follow. States are indicated in the rows, and events are read in the columns. State transitions and actions are represented in the form action/new-state. Actions caused by the same event are represented as action1 &action2&....&actionN. Alternative choices are rapresented as action1 |action2 or event1 |event2.

Master State Transition Table

<table>
<tr><th></th><th>State
1
NON-ACTIVE</th><th>
2
DISCONNECTED</th><th>
3
CONNECTED</th></tr>
<tr><th>Events</th><th></th><th></th><th></th></tr>
<tr><td>ISA+</td><td>st+/2</td><td>2</td><td>3</td></tr>
<tr><td>ISA-</td><td>1</td><td>(st-&sshd)/1</td><td>(st-&sshd)/1</td></tr>
<tr><td>STO</td><td>np/1</td><td>2</td><td>(sc+&(ssnc|smdr))/(3|2)*</td></tr>
<tr><td>NFT</td><td>1</td><td>ssnc/2</td><td>3</td></tr>
<tr><td>RSCR</td><td>1</td><td>sokc/3</td><td>(st++&(sokc|srjc))/3**</td></tr>
<tr><td>RSDR</td><td>1</td><td>2</td><td>(st++&sokd)/(3|2)***</td></tr>
<tr><td>RINF</td><td>1</td><td>2</td><td>(st++&sc-&ssnc)/3</td></tr>
<tr><td>RGRU</td><td>1</td><td>2</td><td>(st++&sc-&ssnc)/3</td></tr>
<tr><td>RMCR</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>RMDR</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>ROKC</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>ROKD</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>RRJC</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>RSHD</td><td>1</td><td>2</td><td>st++/3</td></tr>
<tr><td>RSNC</td><td>1</td><td>2</td><td>st++/3</td></tr>
</table>

(*) *ssnc* in the normal transmission, ***smdr*** in case a Slave reached the maximum allowed of empty slot. The transition to state 2 takes place only incase an ***smdr*** is transmitted and there is only one station connected.
(**) sokc in a normal transition, srjc in the case the maximun number of slave station allowed within the cell is reached.
(***) Goes to state 2 only if *sokd* is sent and there is only one station connected.

In the following we briefly describe the meaning of the previous mentioned states, events and actions.

States

- NON-ACTIVE: The Master station cannot do activity on the network;
- DISCONNECTED: The Master station is active but no one Slave is connected;
- CONNECTED: At least one Slave is connected to the Master.

Events

- ISA+: Related to "ISA switch on" user command [5];
- ISA-: Related to "ISA switch off' user command;
- STO: Synchronization timeout;

- NFT New Frame Transmitted (a new frame is inserted in the transmission queue);
- RSCR Received Slave Connection Request;
- RSDR Received Slave Disconnection Request;
- RINF Received Information for Slave;
- RGRU Received Generation Rate Updating;
- RMCR Received Master Connection Request;;
- RMDR Received Master Disconnection Request;
- ROKC Received Acknowledge Connection;
- ROKD Received Acknowledge Disconnection;
- RRJC Received Rejected Connection;
- RSHD Received Shutdown;
- RSNC Received Synchronization.

<u>Actions</u>

- smcr Sent Master Connection Request;
- smdr Sent Master Disconnection Request;
- sokc Sent Acknowledge Connection;
- sokd Sent Acknowledge Disconnection;
- srjc Sent Rejected Connection;
- sshd Sent Shutdown;
- ssnc Sent Synchronization;
- st+ Synchronization timer start;
- st++ Synchronization timer restart;
- st- Synchronization timer stop;
- sc+ Counter slot increment;
- sc- Counter slot reset for transmitter Slave;
- np Not possible (timer is stopped!).

Slave State Transition Table

Events	State 1 NON-ACT.	2 DISC	3 WAIT-CN	4 CONN	5 WAIT-DS	6 TRANS.
ISA+	2	2	3	4	5	6
ISA-	1	1	ct-/1	dt-/6	6	1
DIC	1	2	ct-/2	dt+/4	5	6
CTO	np/1	np/2	A*	np/4	np/5	np/6
DTO	np/1	np/2	np/3	dt-/5	np/5	np/6
NTO	np/1	np/2	nt-/2	nt-/2	nt-/2	nt-/l
NFT	1	(ct+&nt+)/3#	3	4**	5	6
GRX	np/1	np/2	np/3	4***	5	6
RSCR	1	2	3	4	5	6
RSDR	1	2	3	4	5	6
RINF	1	2	3	4	5	6
RGRU	1	2	3	4	5	6
RMCR	1	ct+/3	sscr/3	B	ssdr/5	ssdr/6
RMDR	1	2	ct-/2	dt-/2	2	1
ROKC	1	2	ct-/4	B	ssdr/5	ssdr/6
ROKD	1	2	3	B	2	1
RRJC	1	2	ct-/2	B	ssdr/5	ssdr/6
RSHD	1	2	ct-/2	dt-/2	2	1
RSNC	1	2	ct-&sscr/3	B****	ssdr/5	ssdr/6

where A ((ct++&sscr)/3)|(ct-/2)
B (sgru|sinf|na)/4

(#) The timer signaling the no activity by the Master station is restarted upon reception of a valid packet in states 3, 4, 5 e 6.
(*) The first timeout of the connection timer yields *(ct++ &sccr)/3* whereas the second *ct-/2*.
(**) The frame queuing for transmission and it is sent when the enabling signal from the master is receiving.
(***) The action is activated by *sgru*, when the enabling signal from the master is receiving.
(****) The choice is made according to *grx/nft/(empty* queue) respectively.

States, events and actions related to Slave stations are described in the following.

States

- NON-ACTIVE — The Slave station cannot do activity on the network;
- DISCONNECTED — The Slave station is active but it is not connected;
- WAIT-CONN — The Slave station is waiting for connection and to receive its local identifier;
- CONNECTED — The Slave is connected to the Master;
- WAIT-DISC — The Slave is waiting for disconnection; the final state upon receiving Acknowledge Disconnection is DISCONNECTED;
- TRANSITION — The Slave is waiting for disconnection; the final state upon receiving Acknowledge Disconnection is NON-ACTIVE.

Events

- ISA+ — Related to "ISA switch on" user command;
- ISA- — Related to "ISA switch off' user command;
- DIC — Related to "ISA disconnect" user command;
- CTO — Connection timeout;
- DTO — Disconnection timeout;
- NFT — New Frame Transmitted (a new frame is inserted in the transmission queue);
- GRX — Generation Rate Variation exceeding threshold;
- RSCR — Received Slave Connection Request;
- RSDR — Received Slave Disconnection Request;
- RINF — Received Information for Slave;
- RGRU — Received Generation Rate Updatin;
- RMCR — Received Master Connection Request;
- RMDR — Received Master Disconnection Request;
- ROKC — Received Acknowledge Connection;
- ROKD — Received Acknowledge Disconnection;
- RRJC — Received Rejected Connection;
- RSHD — Received Shutdown;
- RSNC — Received Synchronization.

Actions

- sscr — Sent Slave Connection Request;
- ssdr — Sent Slave Disconnection Request;
- sinf — Sent Information;
- sgru — Sent Generation Rate Updating;
- ct+ — Connection timer start;
- ct++ — Connection timer restart;
- ct- — Connection timer stop;
- dt+ — Disconnection timer start;
- dt- — Disconnection timer stop;
- na — No action (transmission queue is empty!);
- np — Not possible (timer is stopped!).

5. Conclusions

We have presented in some detail the state transition tables of the AVC-R-ISA MAC protocol. AVC-R-ISA is actually running as MAC access protocol on a network covering north west part of Italy. The network is the test-bed for the connection of local networks. Slave stations act as local area routers while the master station, well positioned on a 5,000 ft top, manages the half-duplex channel, on the 70 cm band, according to the ISA algorithm. AVC-R-ISA is on the air since half year and this protocol machine represents the last version of an accurate and necessary tuning effort.

References

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