Transducer Models of Retransmission Protocols for Noisy Channels

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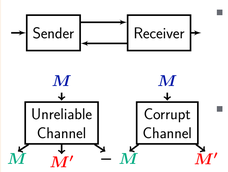
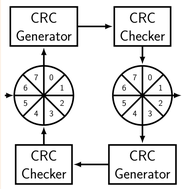
Introduction

Communication System



- Communication channel between sender and receiver can be unreliable.
- Aim: To transfer the message successfully from sender to receiver, without any error.

Retransmission Protocols



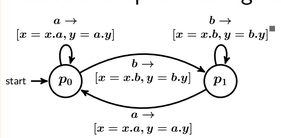
- They are used to ensure that a sequence of frames is delivered in order and without errors despite of transmission errors.
- Reliable delivery is achieved using acknowledgements with re-transmission paradigm.

Cyclic Redundancy Check

- The *cyclic redundancy check (CRC)* is a common technique for detecting errors in data transmission.
- Given a fixed generator polynomial, we build an SST to encode a message string into a cyclic redundancy check (CRC) codeword.

Streaming String Transducer

- An SST reads an input string in a single left-to-right pass and produces the output string using a finite set of states.
- It also uses a finite set of string variables to store strings over the output alphabet.
- On each input symbol, it may transition to another state and update string variables.

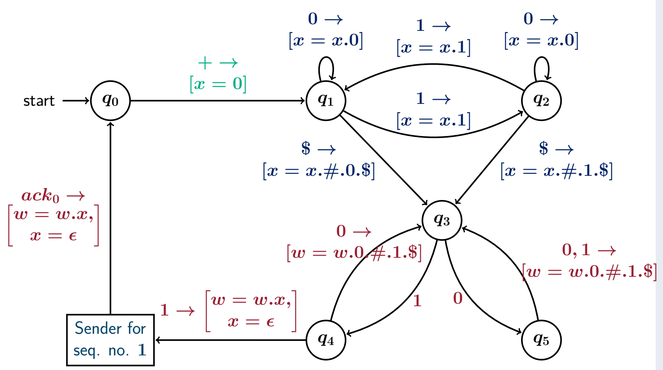


- A string variable can be used at most once across the right-hand side of the parallel assignment.

Protocol Models

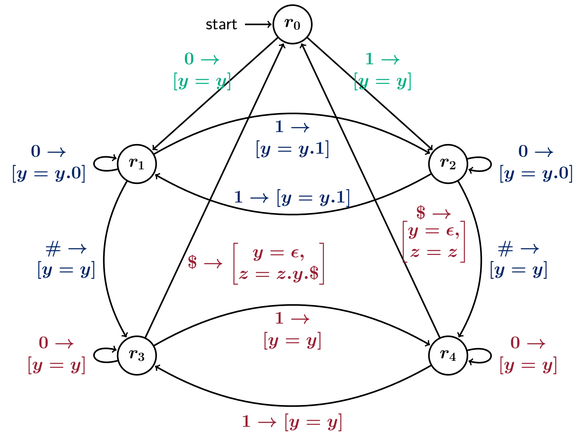
Sender SST for SWP

- The sender receives a message and encodes it into a frame with sequence number, message content and checksum.
- The sender outputs a correct frame upon receiving a positive ACK and a corrupt frame upon receiving a negative ACK.
- String variable x plays the role of the sender's buffer.



Receiver SST for SWP

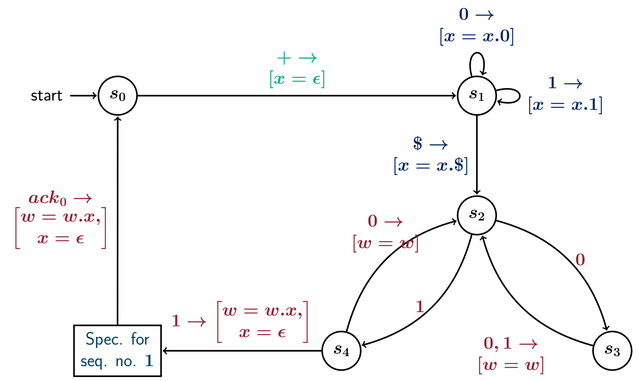
- It distinguishes between the correct and corrupt frames.
- For the correctly received frame, it removes sequence number and checksum and passes the message to its client.



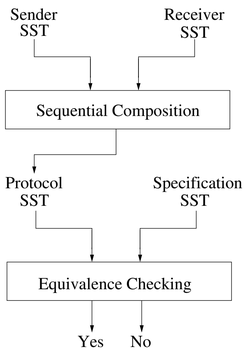
Verification Approach

Specification SST for SWP

- Key Property: Messages acknowledged by the receiver are delivered to the receiver's client correctly and in the same order in which the client of the sender handed them to the sender.
- The *specification SST* does not encode checksum computation, noisy outputs and repeated retransmissions.
- The input to the specification transducer is a sequence of messages and acknowledgements (similar to the sender) and the output is a sequence of correctly delivered messages (similar to the receiver).



The Verification Layout



- Verification Problem: To check *functional equivalence* between the specification and the protocol model.
- The output of the sender is the input of the receiver.
- The model for the entire protocol is obtained by sequentially composing the two.

Wrapping Up...

Case studies

1. **TinyOS** : The SerialP [1] software module of TinyOS computes the checksum and uses the stop-and-wait protocol in the host-to-mote direction.
2. **HDLC** : HDLC [2] is a bit-oriented protocol, that operates at data link layer. Its software implementations compute checksum and use go-back-n protocol.

Conclusions and Future Work

- Our work allows explicit modeling of message contents yet enables algorithmic verification of the resulting protocol models.
- In the future, we will try to permit arbitrary bit corruption using non-deterministic version of SSTs.
- Bounding the number of retransmission rounds can also be useful to extend the protocol models.

Related Work

- Several automated techniques abstract messages to model and verify these protocols [3], whereas we model a message as a bit stream. Hence, we use SSTs to model these protocols.
- SSTs are closed under sequential composition [4] and the equivalence problem for SSTs is decidable [5].

References

[1] http://www.tinyos.net/tinyos-2.x/doc/html/tep113.html.

[2] ISO, "Data Communication - HDLC Procedures - Elements of Procedure," Tech. Rep. ISO 4335, International Organization for Standardization, 1979.

[3] F. Babich and L. Deotto, "Formal Methods for Specification and Analysis of Communication Protocols," *IEEE Comm. Surveys and Tutorials*, vol. 4, no. 1, pp. 2–20, 2002.

[4] R. Alur and P. Cerný, "Expressiveness of streaming string transducers," in *FSTTCS*, pp. 1–12, 2010.

[5] R. Alur and P. Cerný, "Streaming Transducers for Algorithmic Verification of Single-pass List-processing Programs," in *POPL*, pp. 599–610, 2011.