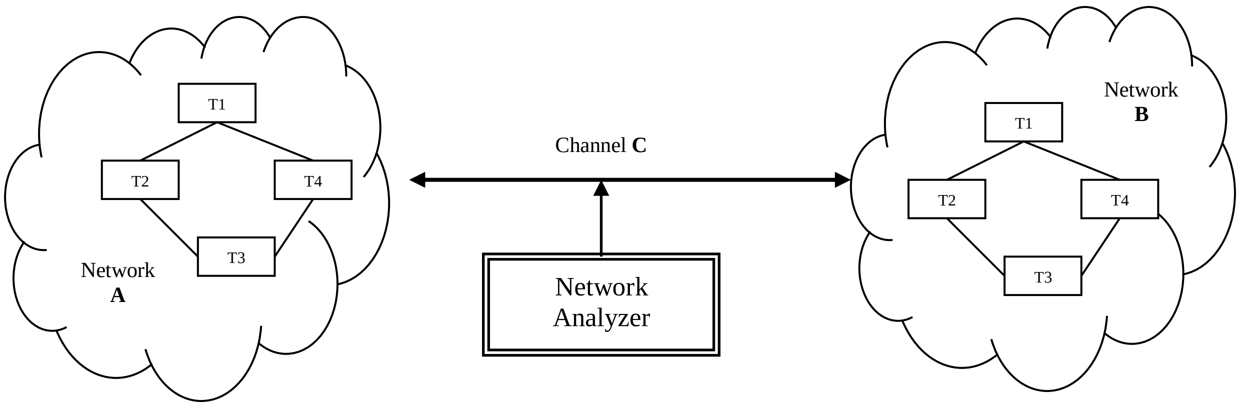
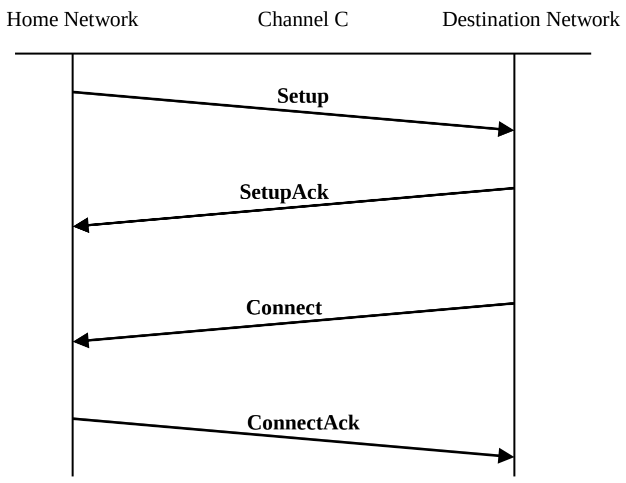
UNITS 7 AND 8: SEMANTIC ANALYSIS and ERROR HANDLING

There are two terminal networks (A and B) connected by a half-duplex C transmission channel (transmitted in both directions, but not at the same time). It also has a network analyzer that reads the messages that circulate through the channel



When one terminal of a network wants to establish a communication with a terminal of the other network, four messages are exchanged through channel C described by the following protocol:



From the home network a **Setup message** is sent to the destination network indicating that it wants to establish a communication with a specific machine of that network. The destination network must respond with a **SetupAck** message as acknowledgment of the received **Setup** message. Once the destination network terminal accepts the call request, it must send a **Connect message** to the terminal of the source network. The source network must respond with a **ConnectAck** as an acknowledgment of the received Connect message.

Each message consists of a series of Information Elements (**EI**). Each **EI**, in turn, consists of two fields. The first field always has a size of 1 byte and its value corresponds to the identifier of that **EI**. The second field will be the **EI** argument and its size depends on the **EI**.

The messages with the **EI**s of which they are composed are described below. These **EI** must appear in the order shown in the following table. The **EI** of a message may be mandatory or optional. Mandatory **EI** must always be included in the message. The optional **EI**s may or may not appear.

MESSAGE	**Information Elements**	**Mandatory / Optional**
Setup	EISetup	Mandatory
	EIAddress	Mandatory
	EIOrigin	Optional
	EIDestination	Mandatory
SetupAck	EISetupAck	Mandatory
	EIDirection	Mandatory
Connect	EIConnect	Mandatory
	EIDirection	Mandatory
ConnectAck	EIConnectAck	Mandatory
	EIDirection	Mandatory

The following table describes the defined **EI** with the description of the fields of which it is composed. For each field its size in bytes and its value are indicated. The first field always has a fixed value since it is the identifier of the **EI** and the second field has a variable value that corresponds to the argument of described **EI**:

		FIELDS					
		Field 1 (Identifier EI)			**Campo 2 (Identifier EI)**		
		Name	**Size**	**Value**	**Name**	**Size**	**Value**
EI	EISetup	IDSetup	1 byte	‘A’	CREF	1 byte	[A-Z,a-z,0-9] Any alphabetic or numeric character
	EISetupAck	IDSetupAck	1 byte	‘B’	CREF	1 byte	Same that Setup
	EIConnect	IDConnect	1 byte	‘C’	CREF	1 byte	Same that SetupAck
	EIConnectAck	IDConnectAck	1 byte	‘D’	CREF	1 byte	Same that Connect
	EIDirection	IDDirection	1 byte	‘E’	Direction	1 byte	A→B = ‘0’ B→A = ‘1’
	EIOrigin	IDOrigin	1 byte	‘F’	Origin	3 bytes	$[0-9]^3$. Three digits
	EIDestination	IDDestination	1 byte	‘G’	Destination	3 bytes	$[0-9]^3$. Three digits

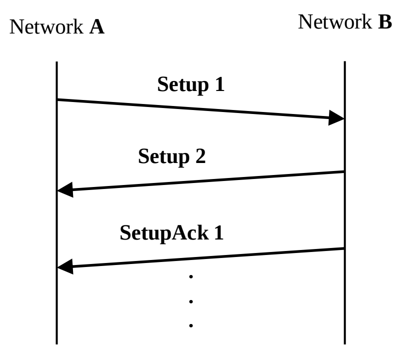
Since messages of several different communications can be circulated through the same channel, it is possible that a message of another communication appears between the four messages corresponding to the same communication. In order to identify the communication to which a message belongs, the CREF field of **EISetup, EISetupAck, EIConnect** and **EIConnectAck** is used. Therefore, the four messages of which a communication is composed must contain the same value in their CREF argument of said Information Elements.

On the other hand, the **EI** EIDirection indicates whether the message has been transmitted in the A→B or B→A direction. Its possible values are '0' or '1' respectively.

EIOrigin and EIDestination contain in their argument the address of the origin and destination terminals respectively.

Example:

Imagine that a **Setup** is sent from A to B, but before receiving the **SetupAck** from B, a **Setup** from B to A corresponding to another communication has been sent



The network analyzer would collect the following data:

$$\underbrace{\underbrace{A\;4}_{\text{EISetup}}\;\underbrace{E\;0}_{\text{EIDirection}}\;\underbrace{F\;3\;1\;2}_{\text{EIOrigin}}\;\underbrace{G\;4\;7\;5}_{\text{EIDestination}}}_{\text{Message Setup 1}}\;\underbrace{\underbrace{A\;8}_{\text{EISetup}}\;\underbrace{E\;1}_{\text{EIDirection}}\;\underbrace{G\;1\;3\;4}_{\text{EIDestination}}}_{\text{Message Setup 2}}\;\underbrace{\underbrace{B\;4}_{\text{EISetupAck}}\;\underbrace{E\;1}_{\text{EIDirection}}}_{\text{Message SetupAck 1}}$$

It is required:

1. Describe formally the automaton that the network analyzer uses as a lexical analyzer, whose tokens are the Elements of Information (**EI**).

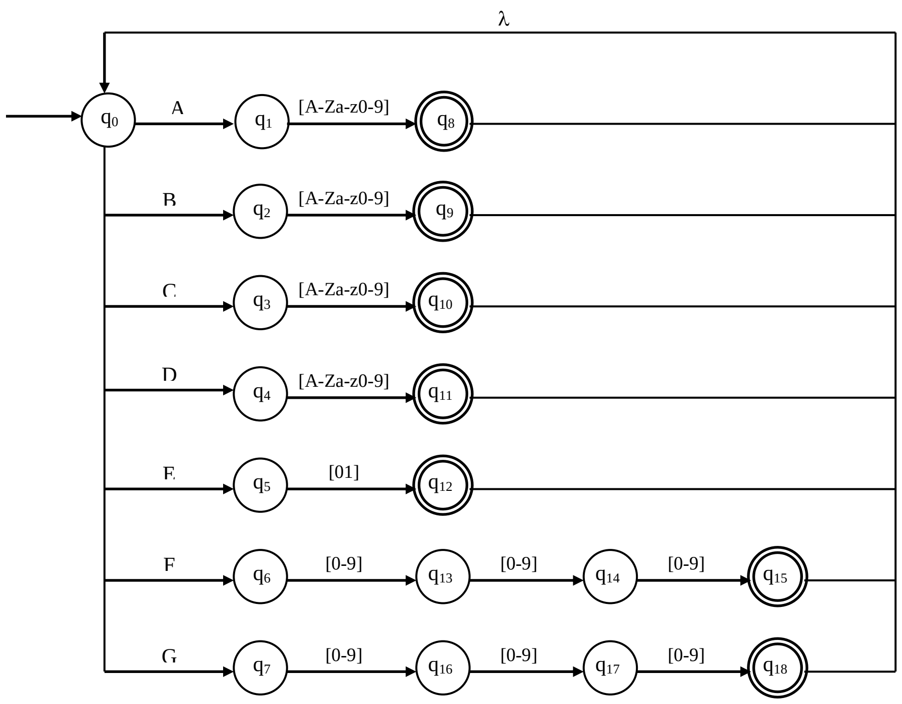
2. Define a grammar that generates messages that can be read on channel C. Is it LL(1)?. Otherwise, make the necessary modifications to make it.

3. Can the grammar of the second exercise be used to perform an LR(1) analysis? If not, modify it to make it so. Generate the first 8 states of the LR(1) analyzer for that grammar.

4. Describe the semantic routines that should be added to the grammar, as well as the additional data structures (table of symbols, stacks, etc.) necessary to control whether the four messages corresponding to a communication have been received and in their correct order. In the case of correctly reading all messages of a communication, they will be printed on the analyzer screen. If an erroneous message is received, an error will also be printed with the Failed Message. Optionally, when an erroneous message is read, additional information can be given, for example, that a **Connect** has been read without having read the **SetupAck**. In this case you can print the **Setup** and the **Connect** and notify the incident.

Solution

For the implementation of the lexical analysis, we are going to use a non-deterministic finite automaton as the one shown below:



The formal description is;

$$NFA = (\Sigma_T, \{q_0..q_{18}\}, q_0, f, F)$$

$$\Sigma_T = \{A\text{-}Z, a\text{-}z, 0\text{-}9\}$$
$$F = \{q_8, q_9, q_{10}, q_{11}, q_{12}, q_{15}, q_{18}\}$$

$f(q_0, A) = q_1$	$f(q_8, \lambda) = q_0$
$f(q_0, B) = q_2$	$f(q_9, \lambda) = q_0$
$f(q_0, C) = q_3$	$f(q_{10}, \lambda) = q_0$
$f(q_0, D) = q_4$	$f(q_{11}, \lambda) = q_0$
$f(q_0, E) = q_5$	$f(q_{12}, \lambda) = q_0$
$f(q_0, F) = q_6$	$f(q_{13}, \{0\text{-}9\}) = q_{14}$
$f(q_0, F) = q_7$	$f(q_{14}, \{0\text{-}9\}) = q_{15}$
$f(q_1, \{A\text{-}Z,a\text{-}z,0\text{-}9\}) = q_8$	$f(q_{15}, \lambda) = q_0$
$f(q_3, \{A\text{-}Z,a\text{-}z,0\text{-}9\}) = q_{10}$	$f(q_{16}, \{0\text{-}9\}) = q_{17}$
$f(q_4, \{A\text{-}Z,a\text{-}z,0\text{-}9\}) = q_{11}$	$f(q_{17}, \{0\text{-}9\}) = q_{18}$
$f(q_5, \{01\}) = q_{12}$	$f(q_{18}, \lambda) = q_0$
$f(q_6, \{0\text{-}9\}) = q_{13}$	
$f(q_7, \{0\text{-}9\}) = q_{16}$	

When a token is read, it returns to the initial state q0 to read the next one. In the table, f (qi, {c1, ..., cn}) = qj means that the transition is made with any of the characters that appear between braces.

The final states generate the following tokens:

sTATE	Token
q_8	(EIsetup, A)
q_9	(EIsetupack, B)
q_{10}	(EIconnect, C)
q_{11}	(EIconnectack, D)
q_{12}	(EIDirection, [01])
q_{15}	(EIOrigin, $[0\text{-}9]^3$)
q_{18}	(EIDestination, $[0\text{-}9]^3$)

A posible grammar is:

1 S ::= M S
2 ::= λ
3 M ::= eisetup EIDirection O EIDestination
4 ::= eisetupack EIDirection
5 ::= eiconnect EIDirection
6 ::= eiconnectack EIDirection
7 O :: EIOrigin
8 ::= λ

To create the LL(1) analyzer, we start with the FIRST and FOLLOW set:

Σ_N	FIRST	FOLLOW
S	eisetup, eisetupack, eiconnect, eiconnectack, λ	$
M	eisetup, eisetupack, eiconnect, eiconnectack	eisetup, eisetupack, eiconnect, eiconnectack, $
O	EIOrigin, λ	EIDestination

The LL table is:

Σ_T	S	M	O
eisetup	1	3	
eisetupack	1	4	
eiconnect	1	5	
eiconnectack	1	6	
EIDirection			
EIOrigin			7
EIDestination			8
$	2		

This table is LL(1).

To know if it is LR(1) it is necessary to generate the table LR(1) and check that there is no problem. The first eight states generated from the grammar of the previous exercise will be.

State 0	Action	Go To
S' ::= •S		(0, S) = 1
S ::= •M S		(0, M) = 2
::= λ	(0, $) = R2	
M ::= •eisetup EIDirection O EIDestination	(0, eisetup) = D3	
::= •eisetupack EIDirection	(0, eisetupack) = D4	
::= •eiconnect EIDirection	(0, connect) = D5	
::= •eiconnectack EIDirection	(0, connectack) = D6	

State 1		Action	Go To
S’	::= S •	(1, $) = Aceptar	

State 2		Action	Go To
S	::= M • S		(2, S) = 7
S	::= •M S		(2, M) = 2
	::= λ	(2, $) = R2	
M	::= •eisetup EIDirection O EIDestination	(2, eisetup) = D3	
	::= •eisetupack EIDirection	(2, eisetupack) = D4	
	::= •eiconnect EIDirection	(2, connect) = D5	
	::= •eiconnectack EIDirection	(2, connectack) = D6	

State 3		Action	Go To
M	::= eisetup • EIDirection O EIDestination		

State 4		Action	Go To
M	::= eisetupack • EIDirection		

State 5		Action	Go To
M	::= eiconnect • EIDirection		

State 6		Action	Go To
M	::= eiconnectack • EIDirection		

State 7		Action	Go To
S’	::= M S •	(7, $) = R1	

To be able to control that the flow of messages between communications is correct, a database or a list should be used in which each record should contain the messages corresponding to a communication. The fields of the records would be:

Field	Type
CREF	char
Direction	char
Origen	char[3]
Destino	char[3]
Setup	boolean
SetupAck	boolean
Connect	boolean
ConnectAck	boolean

The CREF field saves the CREF value of the concrete communication. Direction has the value of the direction of the Message Setup that originated the communication. Origin and Destination contain the addresses of the origin and destination terminals of the communication respectively. The Setup, SetupAck, Connect and ConnectAck fields are boolean values that indicate whether the message was received.

The conjunction of the CREF and Direction fields can be used as a primary key in such a way that when a Setup is received, it must be verified that there is no other communication with the same CREF and originated from the same side of the network. It is possible that there are two communications with the same CREF, one originating in network A and another originated in B.

Therefore, the semantic routines that would have to be performed would be:

When a Setup is read, it is checked in the list that there is no register with the same CREF and Direction as the read Setup. If it already existsd, an Error Message would be printed. If it does not exist, a register is added in the list with the value CREF and Direction of the Message received, the Setup field with value TRUE (this field does not have much direction because it will always be TRUE, but if later you want to add more functionality, we include it). The SetupAck, Connect and ConnectAck fields will have the value FALSE since these Messages have not yet been received.

When a SetupAck is read, the list is searched if there is a register with the same CREF and with Direction opposite to the SetupAck. In case of finding it, it is verified that the only field with value TRUE is Setup. If any of these conditions fail, the corresponding Error Message will be given.

When a Connect is read, the same applies as with SetupAck, but now it must be checked that the Setup and SetupAck fields are TRUE.

When a ConnectAck is read, the same check is made as with the previous Messages. In case all the conditions are validated, it means that the four Messages of the communication have been received, so the corresponding Message will be printed, and the register will be deleted from the list to avoid that when a new communication with the same is generated CREF does not reject it because there is already a communication with that CREF. In turn, a timer can also be used to eliminate the registers of communications that have lost a Message.

The structure of the registers could be:

```
struct reg {
        char CREF;
        char direction;
        int setup = 0;
        int setupack, = 0;
        int connect = 0;
        int connectack = 0;
}
```

The functions applied to the list are:

- `void InsertRegister(char CREF, char direction,`
  `                     char *origin, char *destination);`
  Inserts a register in the list with th given arguments and sets the value 1 in Setup (TRUE).

- `struct reg *SearchCom(char CREF, char direction);`
  Returns a pointer to the item in the list or NULL if it does not exist.

- `void ModifyRegister(struct reg);`
  Modify the register given as an argument.

- `void EliminateRegister(struct reg);`
  Eliminate the register given as an argument.

- `void Print(struct reg);`
  Prints the fields CREF, Direction, Origin and Destination.

The semantic routines that can be included in the rules of the grammar could be:

M ::= eisetup EIDirection O EIDestination

```
M.Code :=    if (register=BuscaCom(eisetup.value, EIDirection.value) == NULL))
                 if (O.exist == TRUE)
                     InsertRegister(eisetup.value, EIDirection.value, O.lexema, EIDestination.lexema)
                 else
                     InsertRegister(eisetup.value, EIDirection.value, NULL, EIDestination.lexema)
             else {
                 error("Comunication established:");
                 Print(register);
             }
```

M ::= eisetupack EIDirection

```
M.Code :=    if (EIDirection.value=='0')
                 direction = '1'
             else
                 direction = '0';
             if (register=SearchCom(eisetup.value, direction) == NULL)) {
                 error("We have not received Setup of:");
                 Print(register);
             }
             else
                 if (register.setupack==1) {
                     error ("SetupAck duplicado");
                     Print(register);
                 }
                 else {
                     register.setupack = 1;
                     ModifyRegister(register);
                 }
```

M ::= eiconnect EIDirection

```
M.Code :=    if (EIDirection.value=='0')
                 direction = '1'
             else
                 direction = '0';
             if (register=BuscaCom(eisetup.value, direction) == NULL)) {
                 error("We have not received Setup of:");
                 Print(register);
             }
             else
                 if (register.connect==1) {
                     error ("Connect duplicated");
                     Print(register);
                 }
                 else {
                     register.connect = 1;
                     ModificaRegister(register);
                 }
```

M ::= eiconnectack EIDirection	

M.Code :=	if (register=SearchCom(eisetup.value, EIDirection.value) == NULL)) {
	    error("We have not received Setup of:");
	    Print(register);
	}
	else {
	    Print(register);
	    EliminateRegister(register);
	}

O ::= EIOrigin
O.exists := TRUE

O ::= λ
O.exists := FALSE