RFM69 Session Key Library

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Introduction

This enhances the standard RFM69 library (https://github.com/LowPowerLab/RFM69) by adding functions to exchange secured data messages between RFM69 transceivers. It is using one times session key handshake scheme developed by Dan Woodruff.
This library is to be used concurrently with a special version of the RFM69 Library: (https://github.com/TomWS1/RFM69/tree/virtualized). The actual one used is updated version covering the latest changes of the standard library of March 2015.

Also, the RFM69 Session Library described hereunder is a modified version of the original one, with the following improvements:

1. One Byte Random Session Key is replaced by a 4 Bytes Session Key as a snapshot of the system time at the moment of the session request
2. Some new public variables are defined for standardization
   - SESSION_KEY_LENGTH 4
   - RF69_HEADER_LENGTH 4
   - SESSION_HEADER_LENGTH RF69_HEADER_LENGTH + SESSION_KEY_LENGTH
   - SESSION_MAX_DATA_LEN RF69_MAX_DATA_LEN - SESSION_KEY_LENGTH
3. A test is done to avoid starting a session with the Broadcast node
4. A test is done at the session receiver to avoid receiving session data when the node is in promiscuous mode
5. 3 ACKs are sent by the receiver at the end of the session instead of one (a best effort attempt to solve undelivered ACK message)
6. New function (setWaitTime) is added, allowing changing the watchdog time between a Session Request and a Session Include handshake, this function uses _waitTime as private variable.

Principle

In secure mode (aka session mode), when a Sender wants to send data to a receiver, it has enter in session with its peer by first requesting a one-time token (aka session key). The receiver will then be ready to receive data message containing the session key. This key is made unique for each session, and one session allows only one data transfer. The session management is obtained by using two bits of the Control Byte (see RFM69 Library), the SESSION_KEY_REQUESTED and the SESSION_INCLUDED bits.
With this mechanism, a hacker having recorded one transfer session will have few chances to reproduce identical transfer by sending endlessly the fake session request and/or data transfer. The chances of success are related to chances the receiver has a session key which is identical to the one that has being recorded.
The security of the data transfer is geared by two principles;

1. A hacker can't guess the session key generation algorithm, to anticipate the one a receiver will expects
2. The algorithm that generates the key has a long or complex rollover mechanism

For the first point it is obvious that the transaction is to be encrypted.
For the second point, the original library uses a pseudorandom generated Byte, which we believe has a too short rollover scheme, therefore the session key is modified to be a 4 Bytes as the system uptime snapshot,. The system time as a rollover period (if no intermediate reboot) of approximately 59 days.

Working cases

1. Both Sender and Receive nodes have session key disabled: There is no session key negotiation, this is the default RFM69 mode
2. Both Sender and Receive nodes have session key enabled. This is the secure transaction mode, see description below
3. Sender disabled, Receiver enabled. There is no session key negotiation, allowing "fire and forget" messages from nodes that don't require session keys.
4. Sender enabled, Receiver disabled – This configuration doesn't work, because the receiver can't handshake a key.

RFM69 Session Key Library

Evaluation

Pros

- Provides reasonable protection against replay attacks. Helpful for sensitive transactions such as opening a lock or garage door
- It is flexible by the usage of session Key option flag that can be turned on and off according to the capability of the receiver node.

Cons

- While the sender waits for a response it can't receive data during a period controlled by a wait timer. There is the potential of miss connections from other nodes trying to access the sender during this time, which could be a problem on busy networks.
- Data transaction in Session mode takes longer than a normal transaction; 3 to 4 (if ACK requested) exchanges vs. 1 to 2 (if ACK Requested) exchanges.

Examples

Secure transaction

Sender and Receiver have the Session enable option

The following diagram summarizes a normal session key transaction.

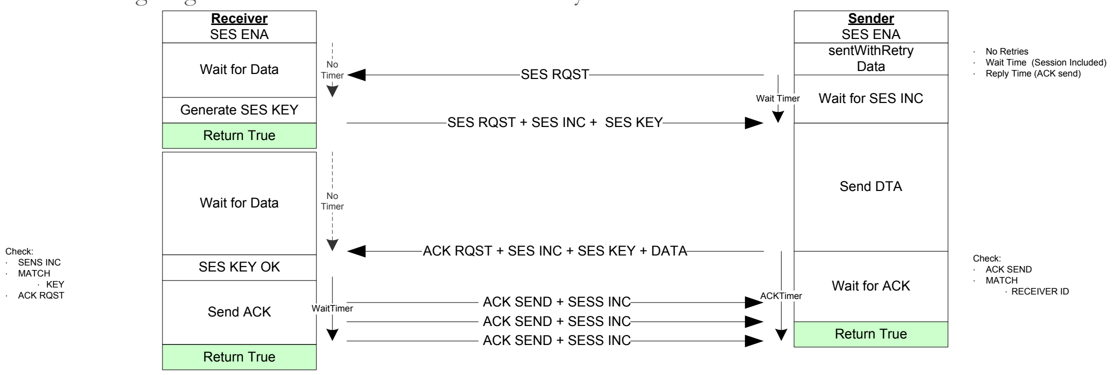


Figure 1: RFM Session Key transaction

Both Sender an Receiver are is session enable (*RFM69_SessionKey::useSessionKey(1)*)
The sender start the session through the following function:
RFM69_SessionKey::sendWithRetry(Receiver, payload, sendSize, 0), meaning no retries with default wait time of 40ms.

- The Sender sends a frame of 0 data Bytes to the receiver with the Session Key Request bit of the control byte set and starts a watchdog timer (the wait time).
- The Receiver looping on *RFM69_SessionKey::recievedDone()* function fetches the sender frame seeing the Session Key Request generates and stores a Session Key of x Bytes (originally a 1 Byte random value , and extended to 4 Bytes as a copy of the current system time)
- The Receiver then sends to the Sender a frame of x Session Key Bytes with the Session Key Request and Session Key Included bits of the control Byte set
- The Sender then sends a data frame with the ACK Request bit of the control byte set (resulting of the initial *setWithRetry* command) together with the Session Included bit set followed by the Session Key
- The Receiver looping on *RFM69_SessionKey::recievedDone()* detects a data frame with the Session Included bit, verifies that the included Session Key matches the last one saved.
  If this is the case, the data is successfully stored in the RFM Data Buffer

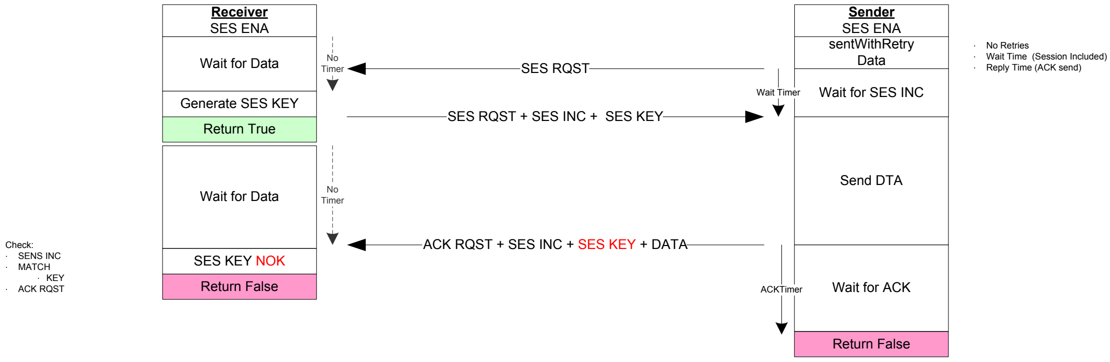
  Notes:
  1. *No Check is done on the Sender ID*
  2. *The sender as no flag indicating that a session is in progress, and is therefore not controlled by a watchdog timer*

- In order to complete the transaction, the Receiver has to check the ACK Request bit through the *RFM69::ACKRequested()* function
- The Receiver replies with a *RFM69_SessionKey::sendACK()* function having the control bits <u>SendACK</u> and <u>Session Included</u>

Note: Practically, with the current version, the sendACK function is repeated 3 times during the wait time, to ensure that at least one Acknowledgement is received by the sender, finalizing both send and receive functions positively.

Erroneous cases

Session Key doesn't match



- In this case the Sender function will times out returning a false status, while the receiver will return a false status because the key doesn't match

No Session Key response from the Receiver

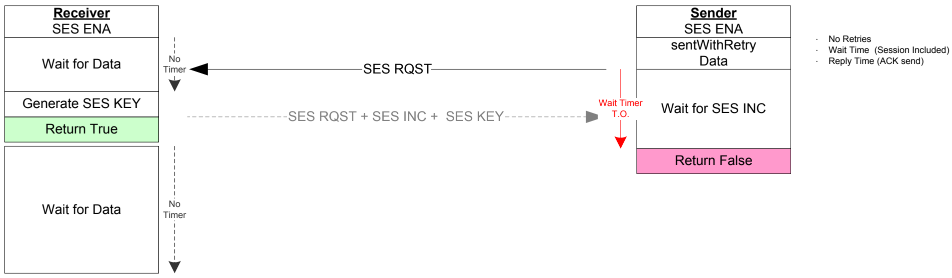


Figure 2: Sender doesn't receive the Session Key

- In this case the Sender function will times out returning a false status, while the receiver will "endlessly" wait for a Data packet with a session Key

Notes:

1. *This is not an issue because if the receiver receives a data packet coming from another node the Control Byte and the Session Key will not match*
2. *If another node tries to initiate a session, a new session key will be computed*

No Data received

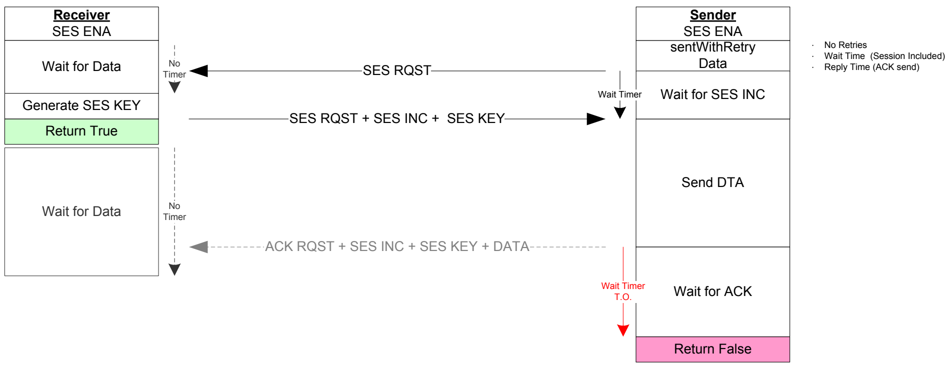


Figure 3: The Receiver doesn't receive the data

- This has an identical result as the previous case.

No ACK received by the Sender

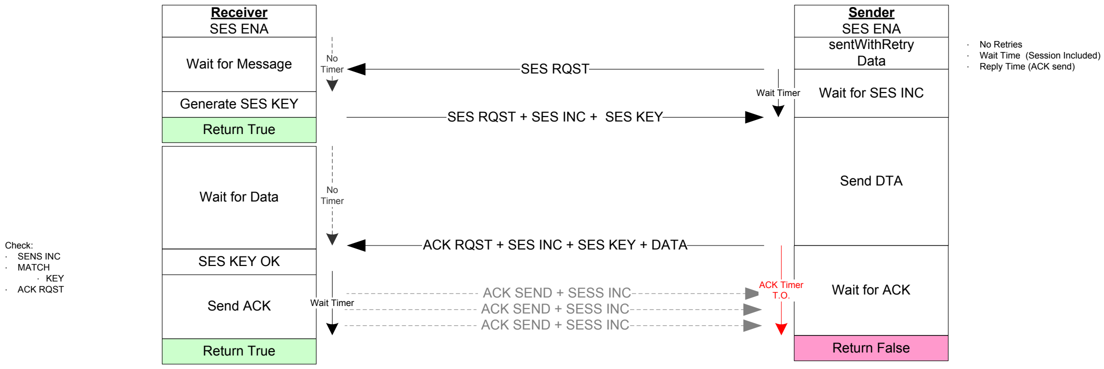


Figure 4: The Sender doesn't receive the Acknowledgement

- In this case the Sender function will times out returning a false status, while the receiver will successfully compute the data.

Notes:

1. *There is no simple solution for that issue*
2. *This situation may be improved by multiplying the acknowledgement during the watchdog window, expecting that at least one ACK will be received*
3. *It can be up to the application software to repeat the data message until an acknowledgement is received (using or not a frame counter to control duplicate data)*
4. *An alternative; if no acknowledgement is required, is to use the RFM69_SessionKey::send() function instead to of the RFM69_SessionKey::sendWithRetry() one, this will also speed-up the transaction.(see figure below), however asymmetrical results may occurs is the session key or the control Byte doesn't match.*

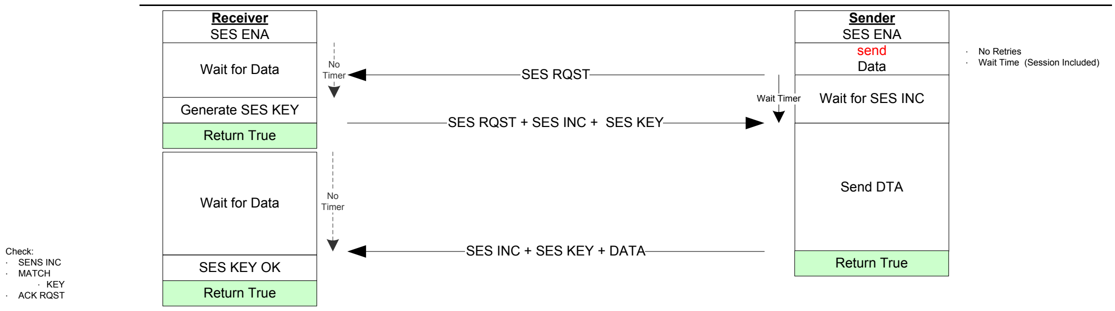


Figure 5: Datagram mode no ACK Requested

- The issue with this option is that if the Sender sends a wrong key, it will not be informed about the failure.

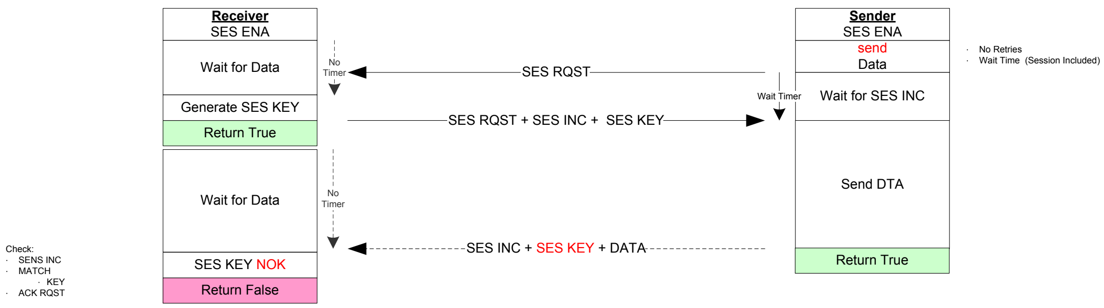


Figure 6: Datagram mode no ACK Requested sender uses a wrong key

RFM69 Session Key Library

RFM69 SessionKey library[1]

Note: The following describes the modified version of RVDB of July 2015

RFM69 SessionKey variables and constants

Configuration Constants

- SESSION_KEY_LENGTH
  The session key length: value is 4
- RF69_HEADER_LENGTH
  RFM standard header length: value is 4
- SESSION_HEADER_LENGTH
  The session header length:
  RF69_HEADER_LENGTH + SESSION_KEY_LENGTH
- SESSION_MAX_DATA_LEN
  The Session maximum data length:
  RF69_MAX_DATA_LEN - SESSION_KEY_LENGTH

Working Variables

- SESSION_KEY_REQUESTED
  0 when false, 0x08 when true
- SESSION_KEY_INCLUDED
  0 when false, 0x04 when true

RFM69 SessionKey Class

Syntax

RFM69_SessionKey
RFM69_SessionKey.initialize
RFM69_SessionKey.useSessionKey
RFM69_SessionKey.sessionKeyEnabled
RFM69_SessionKey. sessionWaitTime
RFM69_SessionKey.send
RFM69_SessionKey.sendACK
RFM69_SessionKey.receiveDone

[1] See https://github.com/dewoodruff/RFM69_SessionKey

RFM69 Session Key Library

RFM69_SessionKey

Description

A call to RFM69_SessionKey creates an RFM69_SessionKey object, whose name needs to be provided while calling the class.

Notes

The RFM69_SessionKey inherit of all the RFM69 functions

Syntax

RFM69_SessioKey();

RFM69_SessionKey(uint8_t slaveSelectPin=RF69_SPI_CS, uint8_t interruptPin=RF69_IRQ_PIN, bool isRFM69HW=false, uint8_t interruptNum=RF69_IRQ_NUM)

RFM69(slaveSelectPin, interruptPin, isRFM69HW, interruptNum)

Parameters

- *none:*
  Default slaveSelectPin is RF69_SPI_CS, default interruptPin is RF69_IRQ_PIN, default isRFM69HW is false (RFM69W), default interruptNum is RF69_IRQ_NUM.
- *slaveSelectpin:*
  Used to select an SS pin. Default is determined by the hardware,
  interruptPin:
  Used to select an interrupt pin. By default defined by RFM69.h, i.e. 2 for ATmega328P, ATmega644P ATmega1284P
- *isRFM69HW:*
  Used to indicate the type of RFM69 module (normal RFM69W or high power RFM69HW). Default is false (i.e. RFM69W)
- *interruptNum:*
  Used to select the interrupt number. The default from RFM69.h is 0

Example

```
RFM69_sessionKey.radio;
RFM69_sessionKey radio(10,2,false,0);   // Setup one RFM69W instance with SS on pin 10 and an IRQ pin 2, IRQ number 0
```

RFM69_SessionKey.initialize

Description

This public function initializes the RFM69 registers and returns a Boolean status "true" when terminated. This function must be invoked before any attempt to send or receive data.

Syntax

RFM69_sessionKey.initialize(uint8_t freqBand, uint8_t ID, uint8_t networked=1)

Parameters

- *freqBand:*
  Frequency band to use, this one should match the module specification. Possible values are:
  - RF69_433MHZ
  - RF69_868MHZ
  - RF69_915MHZ
- *ID:*
  - The Node Identification number. Possible values are from 0 to 254 with 255 as the broadcast node ID.
- *networkeID:*
  - The Network Identification number. Possible values are fro 0 to 255, default is 1

Returns

ALWAYS true when initialization is terminated

Notes

1. This function initializes the following parameters before calling the standard RFM69 initialization:

- _sessionKeyEnabled — default session negotiation set to disabled
- SESSION_KEY_INCLUDED — default Control Byte option set to 0
- SESSION_KEY_REQUESTED — default Control Byte option set to 0
- _waitTime — default wait time between Session Request and Session included is 40 ms

2. Encryption is disabled after initialization.
3. The node ID is not saved into the NodeAddress Register (RegNodeAdrs), because address filtering is by default not used.

Example

```
#define NODEID       99
#define NETWORKID    100
#define FREQUENCY    RF69_433MHZ
...
radio.initialize(FREQUENCY,NODEID,NETWORKID);
```

RFM69_SessionKey.useSessionKey

Description

Set or reset the internal *_sessionKeyEnabled* variable, allowing to activate or not the session key negotiation.

Syntax

RFM69_SessionKey.useSessionKey(bool enabled);

Parameters

- *enabled:*
  - The Session Key option. Possible values are 0, false (disabled) or 1, true (enabled), default is disabled

Returns

None

See also

RFM69_SessionKey.useSessionKey

Example

```
radio.useSessionKey(true);
```

RFM69_SessionKey.sessionKeyEnabled

Description

Boolean function that returns the status of the Session Key option

Syntax

RFM69_SessionKey::sessionKeyEnabled()

Parameters

None

Returns

True if Session Key is enabled

See also

RFM69_SessionKey.useSessionKey

Example

```
if (radio.sessionKeyEnabled()) Serial.println ("Session Key is Enabled");
 else Serial.println ("Session Key is Disabled");
```

RFM69_SessionKey. sessionWaitTime

Description

This function allows changing the watchdog time between the Session Request and the Session Included response.

Syntax

RFM69_SessionKey.sessionWaitTime(uint8_t waitTime);

Parameters

- *waitTime*:
  The maximum time in ms between the moment the sender sends a Session Request and the time the receiver answers with a Session Key and a Session Included control Bytes, default is 40ms

Returns

None

Note

By default the wait time is set identical to the default value of the *RFM69.sendWitRetry* function, however changing the retry wait time parameter of the *RFM69.sendWitRetry* function, do not affect the Session wait time. This is the reason why this function was added.

See also

RFM69. sendWithRetry

Example

```
radio.sessionWaitTime(70); // Set the session wait time to 70ms
```

RFM69_SessionKey.send

Description

This function replaces the *RFM69.send* function, it checks for a clear channel (*canSend*) for duration less than RF69_CSMA_LIMIT_MS, before attempting to send (for a duration that should not exceed RF69_TX_LIMIT_MS) the contents of a data buffer (length is restricted to the SESSION_MAX_DATA_LEN). It essentially activates the internal *sendWithSession* function that takes care of the Session key negotiation. Setting the acknowledgement request bit of the control Byte is optional.

Syntax

RFM69_SessionKey.send(uint8_t toAddress, const void* buffer, uint8_t bufferSize, bool requestACK=false)

Parameters

- *toAddress:*
  The destination node ID
- **buffer:*
  A pointer to the data buffer
- *bufferSize:*
  The size of the relevant data part of the buffer. Data will be truncated to the RF69_MAX_DATA_LEN.
- *requestACK:*
  To enforce the acknowledge request bit of the control Byte, default is none

Returns

None

Notes

Using *RFM69_SessionKey.send* with the requestACK bit of the Control Byte true has the same effect than using the *RFM69.sendWithRetry* without retries, however this is not a Boolean function for which a successful transmission can't be tested.

See also

RFM69.sendWithRetry

Example

```
radio.send(10, "Hello", 5);   // Send 5 Bytes of the string "Hello" to node 10 without
ACK request (if the Session Key is enable, a session key negotiation will be started
before data are sent).
```

RFM69_SessionKey.sendACK

Description

A variant of the *send* function that sends to the last received source node ID a data packet the ACK bit and the SESSION_INCLUDED (if the Session Key is enabled) bit of the Control Byte.

Syntax

RFM69_SessionKey.sendACK(const void* buffer = "", uint8_t bufferSize=0)

Parameters

- **buffer:*
  A pointer to the acknowledgement data buffer. By default data is empty
- *bufferSize*:
  The size of the relevant data part of the buffer. Data will be truncated to the RF69_MAX_DATA_LEN. By default the size is set to 0.

Returns

None

See also

RFM69_SessionKey.send
RFM69.ACKReceived

Notes

The original RSSI value of the last received frame is preserved, by this function.
The acknowledge datagram as by default no data; however an ACK datagram may carry data as a normal send function.

Example

```
if (radio.ACKRequested())
    {
      radio.sendACK();
      Serial.println(" - ACK sent");
    }
```

RFM69_SessionKey.receiveDone

Description

This Boolean function sets the RFM69 in receiving mode, allowing RFM69 reception interrupt.
Once interrupt is usefully terminated (on correctly formatted frame with data >0) data of the received frames are accessible through the working variables.
If the Session Key is enabled, only frames > 0 Bytes (not only control ones) with incoming Session Key corresponding to the stored Session Key are validated.

Syntax

RFM69_SessionKey. receiveDone()

Parameters

None

Returns

True if data is received, else false.

When true the following working variables are updated.

RFM69

- DATALEN
- SENDERID
- TARGETID
- PAYLOADLEN
- ACK_REQUESTED
- ACK_RECEIVED
- RSSI

RFM69 Session Key Library

RFM69_SessionKey

- SESSION_KEY_REQUESTED
- SESSION_KEY_INCLUDED

Example

```
  if (radio.receiveDone())
  {
    Serial.print('[');Serial.print(radio.SENDERID, DEC);Serial.print("] ");
    Serial.print(" [RX_RSSI:");Serial.print(radio.readRSSI());Serial.print("]");
    Serial.print(" to [");Serial.print(radio.TARGETID, DEC);Serial.print("] ");
    Serial.print(" ACK Requested: "), Serial.print(radio.ACKRequested());
    Serial.print(" Data Length: "), Serial.print (radio.DATALEN, DEC);
    Serial.print(" Data: "); for (byte i = 0; i < radio.DATALEN; i++)
Serial.print((char)radio.DATA[i]);
    Serial.println();
  }
```

See also

RFM69.ACKReceived()

Appendix

Session Key tracing

Legend:

1 represent RFM69 functions
2 represent RFM69_SessionKey functions

SENDER

2 - sessionKeyEnabled() = true
1 - sendWithRetry(GATEWAYID, payload, sendSize, 0) // *Will NOT initiate Retries and Default wait time = 40ms*
2 - send(GATEWAYID, payload, sendSize, true) // *RQSTACK*
if (sessionKeyEnabled()) // *True > 2 - sendWithSession*
2. - sendWithSession(GATEWAYID, payload, sendSize, true) // *RQSTACK*
SESSIONKEY = 0
2 - sendFrame(GATEWAYID, null, 0, false, false, true, false) // *NO Data, NO RQTTACK, NO SENDACK, **SESRQST** NOSESSINC*
FIFO SPI Transfer 4 Bytes Header with CTRLByte = SESSRQST and SESSIONKEY = 0
while (millis() - sentTime < retryWaitTime && SESSION_KEY == 0); // Check for T.O. and SESSION KEY = 0
2 – receiveBegin () // *reset SESSION Ctl Bytes*
1 – receiveBegin() // *Wait for Interrupt from Receiver*
1 – interruptHandler() // *Get Receiver DATA with basic test (payload length, if not promiscuous, **Target ID or Broadcast ID** match)*
2 - interruptHook(CTLbyte)
if (sessionKeyEnabled() && SESSION_KEY_REQUESTED && SESSION_KEY_INCLUDED)
Check if received data has only SESSRQST and SESINC to read the Session KEY
SPI Transfer SESSION_KEY = KEY
1 – Return to interruptHandler
Save data of payload if included in the ACK
2 – Return to sendWithSession
2 - sendFrame(GATEWAYID, payload, sendSize[2], true, false, false, true)
*//Send Data with **RQSRACK** (from initial), NO SENDACK, NO SESRQST **SESSINC** + **SESSION_KEY***
1 – Return to SendWithRetry [3]
while (millis() - sentTime < retryWaitTime) // *Wait now for the final ACK !!!*
{
if (ACKReceived(GATEWAYID))
1 - ACKReceived(GATEWAYID)
1- receiveDone()
1 – interruptHandler() // *Get Receiver DATA with basic test (payload length, if not promiscuous, Target ID or Broadcast ID match)*
2 - interruptHook(CTLbyte)
if (sessionKeyEnabled() && SESSION_KEY_INCLUDED && !SESSION_KEY_REQUESTED)
Check for data with SESINC only + Check if INCOMING_SESSION_KEY = SESSION_KEY
1 – return to interruptHandler
Save data of payload if included and update the ACK CTRLByte
1 - Return to ACKReceicved()
*True if **ACKRCV** and **Sender ID** **or Broadcast I**D match*
1 – Return true

RECEIVER

2 - receiveDone() *// Wait for Interrupt from Sender (Session Request for instance)*
2 – receiveBegin () // *reset SESSION Ctl Bytes*
1 - receiveBeign()
1 – interruptHandler() // *Get Sender DATA with basic test (payload length, if not promiscuous, Target ID or Broadcast ID match)*
2 - interruptHook(CTLbyte)

[2] No check done on the actual size of the payload which should be max RF69_MAX_DATA_LEN-1

[3] If Retry was specified in the initial command, it will start here

if (sessionKeyEnabled() && SESSION_KEY_REQUESTED && !SESSION_KEY_INCLUDED)

Check if received data has SESSRQST
> Generate Session KEY

2 - sendFrame (SENDERID, null, 0, false, false, true, true)// *NO Data, NO RQTTACK, NO SENDACK, **SESRQST SESSINC***

FIFO SPI Transfer 4 Bytes Header with CTRLByte = SESSRQST and SESSION_KEY = KEY

2 - Return

1- Return

1 – Return

1 – Return (true)

2 - receiveDone() *// Wait for Interrupt from Sender Data with Session for instance)*

2 – receiveBegin () // *reset SESSION Ctl Bytes*

1 - receiveBeign()

1 – interruptHandler() // *Get DATA with basic test (payload length, if not promiscuous, Target ID or Broadcast ID match)*

2 - interruptHook(CTLbyte)

if (sessionKeyEnabled() && SESSION_KEY_INCLUDED && !SESSION_KEY_REQUESTED)

Check for data with SESINC only + Check if INCOMING_SESSION_KEY = SESSION_KEY

1 – return to interruptHandler

Save data of payload if included and update the ACK CTRLByte

2 - Return

1- Return

1 – Return

1 – Return (true)

1 – if (ACKRequested()) // *Necessary to fetch the sendWithSession final ACK Request*

Check the CTLByte for ACK_REQUESTED from any Node address except Broadcasts

2. - sendACK() // *With NO Data*

1 - sendFrame(sender, buffer, bufferSize, false, true) // *With No Data NO RQSTACK but with SENDACK*

1 - Return

-ooOoo-