An analytical model of TNC controller

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Abstract: Abstract. TNC controllers are microprocessor systems, used for data transmission in Packet Radio network that may be considered as an example of a wireless, wide area network. On the basis of Packet Radio infrastructure we may also form telemetric and remote control network using APRS protocol. TNC controllers may cooperate with other similar networks as well. In this paper, an analytical model of TNC controller is presented. It takes into account basic dependencies resulting from transmission protocol properties and operating rules of the controller itself. The model may serve as a reference point during efficiency analysis of various types of TNC controllers.

Keywords: Packet Radio network, TNC controller, efficiency estimation

1. Introduction

Amateur Packet Radio network [2] may be considered as an example of a simple, wireless wide area network [7]. It was developed in early 1980’s, when other connectivity media, such as Internet or cellular telephony, were not widely available yet. Later, despite its interesting properties, Packet Radio – as a deed of radio amateurs – did not achieve high popularity, which can be acknowledged by small quantity of widely available literature on this subject. Nevertheless, radio amateurs could use it for human-to-human communications similarly to current Internet instant messengers (IM).

Nowadays, because of high popularity and availability of Internet and cellular telephony, application of Packet Radio changes for telemetry and remote control, mostly according to the requirements of APRS (Automatic Position Reporting System) protocol [8]. Although it is hard to form a true real-time systems using Packet Radio network and
TNC controllers, these new applications sometimes require that operational parameters of the network, such as effective throughput or transmission delays, can be estimated.

A complete Packet Radio station consists of a computer (or other Data Terminal Equipment type device) and radio transceiver. Because of different methods of information transmission, these devices can not cooperate with each other directly. It is thus necessary to apply specific data format processing techniques. Such a processing may be performed entirely in the computer (at a cost of higher processing power consumption) or by attachment of additional, external circuits dedicated for this application. An example of such a circuit is a TNC controller [1].

The rest of the paper is organised as follows. First, we briefly describe TNC controller structure and functions, as well as basic AX.25 protocol properties with special emphasis on frame format and frame exchange rules. Basing on these explanations, we introduce an analytical model of TNC controller that allows estimate effective transmission speed and transmission delays in a network containing such controllers. Similarly, we can estimate buffer capacity that ensures continuous transmission at the sender side. We also determine the conditions that must be met in order to ensure continuous transmission at the receiver side. Using derived dependencies, we calculate example values for few typical parameters of Packet Radio network and TNC controllers. The paper ends with a brief discussion that summarizes achieved results.

2. TNC controllers and AX.25 protocol

TNC (Terminal Node Controller) [2] is an autonomous, microprocessor-based device used in amateur Packet Radio network. Its main purpose is a connection between a personal computer and radio receiver-transmitter operating in Packet Radio network. Instead of computer, another DTE (Data Terminal Equipment) device, such as programmable controller or weather station, may be used. A typical Packet Radio network station with TNC controller is shown on Fig. 1.

Fig. 1. Typical Packet Radio station with TNC controller.
2.1. TNC controller structure

TNC controller consists of a digital part, that ensures data format processing according to Packet Radio network requirements and rules of AX.25 protocol, as well as analogue part, that plays a function of a modem and makes it possible to control radio transceiver directly from TNC. The block diagram of TNC hardware is presented on Fig. 2. A more detailed description of properties of individual types of TNC controllers may be found in [11].

![Block diagram of TNC controller hardware.](image)

2.2. TNC controller functions

The fundamental task of TNC controller is to process data incoming from attached computer so that its format could meet requirements of the AX.25 protocol, used as a data link layer in Packet Radio network. With this end in view, the controller buffers data, and then places them in adequately formed frames. During sending on radio link, a modulation is used according to the selected transmission rate. It allows for direct connection to radio transceiver and control over its work from TNC. We can therefore say that TNC controller is responsible for proper realisation of AX.25 protocol; however, it does not have radio communication capabilities itself. Thanks to such approach, TNC controllers may be used with any radio transceiver, not only in radio amateur frequency bands.

Functions described above are controlled by a software. It is responsible for proper realisation of network mechanisms, and furthermore, it contains a user interface that allows for, among others, configuration of some controller and radio link parameters, as well as management of logical links with other network stations. Depending on controller type, various methods of computer (user) to controller communication are available. They may be optimised for controller’s cooperation with a human (TAPR and TF
command sets) or a device (HOST and KISS modes). Availability of individual operating modes depends on controller type.

2.3. AX.25 protocol

AX.25 protocol [1], used as a data link layer in Packet Radio network, belongs to the HDLC protocol family and mostly resembles LAP-B. AX.25 uses most of HDLC frame types, frame exchange rules are also similar [1]. Modifications comprise elements characteristic for Packet Radio network and take into account specificity of amateur communications. General format of AX.25 protocol frame is shown on Fig. 3.

Address field contains addresses of 2 to 10 stations. Except the addresses of the sender and the recipient, up to 8 addresses of intermediate stations may be included. Every address contains up to 6 characters – which results from using amateur "call signs" as station addresses – and an additional byte for secondary identification and other purposes. The shortest address field contains therefore 14 bytes, while the longest one – 70. Such a large address part was necessary in earlier implementations of Packet Radio networks, where no network layer was present, hence routing had to be done statically on data link layer level. Nowadays, when several network layers may operate over AX.25 protocol, number of station addresses may be reduced to 2.

![Fig. 3. General frame format in AX.25 protocol.](image)

Control field specifies frame type and, for some types, sequence numbers. Similarly to HDLC, there are I (information), C (control) and U (unnumbered) frames. I-type frames are generally used to carry user data after a logical connection is established. All such frames must be positively acknowledged; otherwise, limited number of retransmission attempts shall occur. U-type frames are used for connection management. Some of them may also carry user data, typically before a logical connection is established; such transmissions are not acknowledged, but allow for broadcast transmissions. Control frames are used mostly for acknowledgments.

PID (Protocol ID) field specifies if there is any network layer above AX.25 and what type it is. One of such layers may be TCP/IP protocol stack. Data field, being found in information and unnumbered frames only, may contain up to 256 bytes. This number may be further limited depending on temporal link quality or other factors.

CRC sum is calculated according to CRC-CCITT algorithm \((x^{16} + x^{12} + x^5 + 1)\) [4]. Depending on whether the received CRC equals to the one calculated from content of the...
received frame, the recipient send positive or negative acknowledge. Similarly to HDLC protocol, several information frames may be commonly confirmed by a single acknowledgement. However, maximum window size is not always used. It depends on format of transmitted information and capabilities of transmission hardware and software.

In order to preserve protocol transparency that might be violated by using special bit sequences as frame delimiters, a so-called "bit stuffing" is applied so that it comprises entire frame content between delimiters. After each sequence of five bits equal to "1", a single "0" bit is inserted into bit stream. In the receiver, this operation is reverted.

Unlike HDLC, but similarly to LAPB, AX.25 protocol uses Asynchronous Balanced Mode, in which all stations are equal to each other. It reflects a philosophy of amateur communications. In ABM mode, all information frames sent by the transmitter must be acknowledged. Few types of acknowledgement frames are possible:

- **RR (Receiver Ready)** – positive with notification that the recipient is ready to accept more information frames;
- **RNR (Receiver Not Ready)** – positive with notification that the recipient is not yet ready to accept more information frames; this allows for flow control;
- **REJ (Reject)** – transmission error;
- **FRMR (Frame Reject)** – serious error, received frame type other than expected in a given protocol state.

RR and RNR frames may acknowledge several I frames, up to selected maximum window size, thus reducing protocol overhead.

### 2.3.1 Parameters of AX.25 protocol

AX.25 protocol and TNC controller behaviour may be adjusted by large number of parameters (depending on TNC software). From the point of view of protocol efficiency, the most important are the following parameters:

- **k** – window size, i.e., maximum number of commonly acknowledged frames; not larger than 127 in protocol version 2.2 and 7 in older versions;
- **N1** – maximum capacity of data field in an information or unnumbered frame; not larger than 256;
- **T2** – time that elapses between the end of latest I frame and acknowledge; depending on software and parameters, this delay may or may not occur during transmission and may be set manually or automatically;
- **T103** – time for stabilisation of transmitter parameters after transmission start and for carrier detection in receiver; depends on radio transceiver capabilities and, in most cases, varies from few tens to few hundreds milliseconds;
- **T102** – slot duration for carrier sense-based collision avoidance; typically about 50 to 300 ms;
– $p$ – persistence parameter of carrier sense-based collision avoidance (not defined by protocol description but implemented in most of the software); typically equal to 63 which means transmission probability of 25%.

2.3.2 Frame exchange rules

AX.25 protocol may operate on half-duplex or full-duplex links. In both cases, before transmission starts, the station must check whether the channel is free. This is done by $p$-persistent carrier sense mechanism. For any given value of $p$ and $T_{102}$, if no collisions take place, average medium access delay may be expressed as

$$T_{CS} = \frac{256 \cdot T_{102}}{2 \cdot (p + 1)}.$$  \hfill (1)

Afterwards, transmitter is turned on. TNC waits for $T_{103}$ to ensure that transmitter works stable and then sends information (I) frame. If window size ($k$) is larger than one and there are enough frames ready for transmission, several I frames may be sent consecutively. When the transmission stops, the receiver waits for $T_{2}$ to ensure there are no more I frames, turns on the receiver, waits for $T_{103}$ and sends the RR frame (acknowledge). Transmission process for window size of 1 and 5 is shown on Fig. 4 and 5, respectively.

![Fig. 4. Frame exchange when $k = 1$.](image)

![Fig. 5. Frame exchange when $k = 5$.](image)

In the case of full-duplex radio link, every I frame is acknowledged separately; however, the corresponding RR frame is sent in a separate transmission channel. Thus, $k$ parameter is not important, because all the I frames are sent, if possible, consecutively in a single long sequence. Some comment is necessary on $T_{2}$ delay. Depending on the software and AX.25 protocol implementation details, the sender may request immediate acknowledge by setting a special control bit (Poll/Final) in the control field of a frame. Only the latest I frame should be marked this way. In such a case, the receiver knows there will be no more
frames and responds with RR immediately, not wasting $T_2$ for unnecessary waiting for more frames. What seems interesting, such behaviour is not required by AX.25 definition and Poll/Final bit usage in this context depends on software. Nevertheless, marking the latest frame in the sequence would be especially useful on a half-duplex link.

3. An analytical model of TNC controller

The analysis comprises the case of data transfer between a pair of computers, connected with two TNC controllers. In such a case – because of buffering of transmitted information in TNC memory and data processing – the transmission runs in multiple stages. The network configuration together with transmission stages is explained on Fig. 7. The times $T_a$, $T_p$ and $T_z$, as well as $T_{SpU/p}$ and $T_{SlDn}$, marked on this figure can be calculated as explained in section 3.1.

Let’s make the following assumptions:
The network consists of two stations, communicating with each other using half-duplex or full-duplex radio link;

- No collisions or transmission errors occur, thus no retransmission are necessary;
- Frame processing time in TNC controllers is negligible.

### 3.1. Effective throughput

In order to estimate effective throughput with respect to presence of two TNC controllers, we need to calculate wireless transmission time between the controllers \( T_p \) as well as wired transmission time at the sender and recipient side \((T_a \text{ and } T_z, \text{ respectively})\).

#### 3.1.1 Wireless transmission time

Wireless transmission time corresponds to the transmission using AX.25 protocol. In Packet Radio network, this protocol may operate on either half-duplex or full-duplex link. In case of half-duplex link, according to the efficiency estimation of AX.25 protocol [10] and taking into account contention time estimated according to (1), transmission time of data, that is \( L_D \) bytes long, equals to

\[
T_p = \left\lceil \frac{L_D}{kN_1} \right\rceil \left( T_2 + T_{CS} + 2T_{103} + T_{RR} \right) + \left\lceil \frac{L_D}{N_1} \right\rceil T_I, \tag{2}
\]

where \( R_{wl} \) is radio link transmission rate,

\[
T_{RR} = \frac{63}{62} \frac{160}{R_{wl}}, \tag{3}
\]

and

\[
T_I = T_{RR} + \frac{63}{62} \frac{8N_1}{R_{wl}} = \frac{63}{62} \frac{160 + 8N_1}{R_{wl}}. \tag{4}
\]

Similarly, in the case of full-duplex radio link transmission time equals to [10]:

\[
T_p = T_{103} + \left\lceil \frac{L_D}{N_1} \right\rceil \cdot T_I + T_R. \tag{5}
\]

Having \( T_p \) for a given link, we can calculate its effective throughput:

\[
V_{wl} = \frac{8 \cdot L_D}{T_p}. \tag{6}
\]

#### 3.1.2 Wired transmission time
Because of the operating rules of TNC, transmission on radio link may start, if there are at least $N_1$ characters collected in the buffer. Thus, assuming that each character is represented by 10 bits (as in RS-232), transmission start delay equals to:

$$T_a = T_{TR} - T_{CT} = \frac{10 \cdot N_1}{R_w},$$

(7)

where $R_w$ is wired link (e.g., RS-232) transmission rate. Assuming that – as in typical case of Packet Radio network and TNC controller application – the effective speed of the wired link significantly exceeds that of radio link, after wireless transmission is finished, the receiving TNC will send no more than $N_1$ characters (gathered from the last AX.25 frame). Thus, we may assume that $T_z = T_{rc} - T_{tr} = T_a$.

### 3.1.3 Effective transmission speed

Therefore, effective transmission speed equals to:

$$V_{ef} = \frac{8 \cdot L_D}{2 \cdot T_a + T_p},$$

(8)

where $T_p$ is calculated according to (2) or (3) if the radio link is half-duplex or full-duplex, respectively.

It is worth notice that the influence of the $T_a$ time upon effective transmission speed decreases, when entire size of the transmitted information grows or when efficiency of the wireless link falls. Thus, when $T_p$ is long enough, $T_a$ time may be neglected. It is equivalent to the assumption that the total transmission time between computers equals to the transmission time between TNC controllers using AX.25 protocol.

### 3.2. Transmission delays

In certain applications, not only effective transmission speed may be important, but also delays resulting from buffering and format processing of transmitted data. It is particularly interesting how much time elapses between transmission start at the sender and reception start at the recipient, and how much time elapses between transmission end at the sender and reception end at the recipient. We will refer these times as transmission start and transmission end delays, respectively.

#### 3.2.1 Transmission start delay

Transmission start delay, corresponding to the "speed-up" phase shown on Fig. 7, is equal to the sum of $T_a$ time calculated according to (4) and transmission time of a single information frame on the radio link, including carrier sense and transmitter start-up times. It is thus equal to
\[ T_{SpUp} = \frac{10 \cdot N_1}{R_w} + T_{CS} + T_{103} + \frac{63}{62} \cdot \frac{160 + 8 \cdot N_1}{R_w} . \] (9)

The explanation of (9) is shown on Fig. 7.

![Fig. 7. Explanation of "speed-up" time (TSpUp) calculation.](image)

### 3.2.2 Transmission end delay

Transmission end delay, corresponding to the "slow-down" phase shown on Fig. 7, is much more difficult to estimate. It results from information buffering in TNC controller memory. When the buffer capacity is sufficiently large, entire information may be transmitted at the sender side continuously, without pauses caused by buffer filling. However, during this time, part of information is already being transmitted on radio link. Because of smaller effective speed of this link, wired transmission at the recipient side is non-continuous. Therefore, in order to estimate the moment of transmission end at the recipient side, we must take into account the moment of wireless transmission completion \((T_{tr} \text{ on Fig. 7})\) and transmission time of no more than \(N_1\) characters on wired link. Wireless transmission is also delayed in relation to transmission at the sender side by the transmission time of \(N_1\) characters on wired link \((T_{CT} - T_{TR} = T_a)\). If this transmission is continuous, we can estimate the moment of its completion easily \((T_{tr} = T_{TR} + T_p)\). Taking into consideration the explanations given above, transmission end delay may be expressed as

\[ T_{SlDn} = 2 \cdot \frac{10 \cdot N_1}{R_w} + T_p - \frac{10 \cdot L_D}{R_w} = 2 \cdot T_a + T_p - \frac{10 \cdot L_D}{R_w} . \] (10)

The explanation of (10) is presented on Fig. 8. An interesting issue is such that wireless transmission ends after \(T_{SlDn}\); however, it does not matter from the point of view of data transmission between computers.
It is worth notice that presented considerations assume that $V_{wl} < V_w$. Otherwise, negative values may be obtained that are obviously invalid. In any case however, the "slow-down" phase should not be shorter than the "speed-up" phase, because, regardless of transmission speeds, there is always $N_1$ data bytes to transmit at the end of the transmission.

Fig. 8. Explanation of "slow-down" time ($T_{S,D_n}$) calculation.

3.3. Buffer capacity

In some applications, it may be necessary to ensure continuous transmission at the sender side. As in most cases wired link is faster than radio one (higher effective speed), transmitted data must be placed in a buffer before it can be processed and sent. Minimum buffer capacity depends on total size of transmitted data as well as on difference between effective transmission speeds of wired and wireless links.

3.3.1 Buffer capacity on sender side

In order to estimate buffer capacity on sender side, we must assume that effective transmission speed of wired link ($V_w$) on the sender side corresponds to average speed of buffer filling. In turn, effective speed of radio link ($V_{wl}$) corresponds to average speed of buffer emptying. Multiplying the difference between them by the time of data transmission on wired link we may calculate approximate buffer size that guarantees continuous transmission on wired link:

$$C = \left( \frac{8 \cdot R_w}{10} - \frac{8 \cdot L_D}{T_p} \right) \cdot \frac{10 \cdot L_D}{8 \cdot R_w} = L_D \cdot \left( 1 - \frac{10 \cdot L_D}{R_w \cdot T_p} \right).$$  (11)

The relation above may be explained as follows. Within $T_w = L_D/V_w$, TNC receives $L_D$ data bytes from the attached computer. However, as $V_{wl} < V_w$, TNC can
transmit wirelessly no more than $V_{wl} T_w = L_D V_{wl} / V_w$ data bytes. Therefore, all remaining data is excessive and must be placed in the buffer. Thus, buffer capacity can be expressed as follows:

$$C = L_D \cdot \left(1 - \frac{V_{wl}}{V_w}\right),$$

which, after some transformations, leads to (11).

It is worth noticing that both (11) and (12) are valid only if $V_{wl} < V_w$. Otherwise, negative values may be obtained that do not make sense in terms of buffer capacity. In turn, if the result is smaller that $N_1$, it must also be discarded because otherwise it would not be possible to fit as much data as necessary to form a frame containing $N_1$ data bytes.

### 3.3.2 Buffer capacity on recipient side

It is also possible to ensure continuous transmission on the receiver side, however, it requires that entire data size ($L_D$) is known by receiving TNC controller. In this case, additional delay of transmission start at the receiver side is necessary. We must also take into account that the data transmission runs from the wireless link to the wired one. Thus, average speed of buffer filling corresponds to the effective speed of the wireless link, while average speed of buffer emptying – to that of wired link.

In practice, continuous transmission on the recipient side requires that entire data is already received by the receiving TNC controller. Otherwise, due to transmission errors, data might not be delivered in time to ensure continuous transmission on recipient’s wired link.

### 4. Example calculations

Results of calculations performed according to formulas derived above for few example parameter sets are collected in Table 1 for the case of a half-duplex link and in Table 2 for the full-duplex one. The following values are calculated:

- transmission time on wireless link ($T_p$),
- effective transmission speed of AX.25 protocol ($V_{wl}$) – between TNC controllers,
- effective transmission speed between computers ($V_{ef}$), taking into account transmission between TNC and computer as well,
- "speed-up" time ($T_{SpUp}$),
- "slow-down" time ($T_{SlDn}$),
- buffer capacity that guarantees continuous transmission at the sender side ($C$).

During the calculations, the following transmission parameters were accepted: $N_1 = 256$ B, $k = 7$, $T_{103} = 250$ ms, $p = 63$, $T_{102} = 100$ ms. These values can be regarded as typical
for Packet Radio network operation, e.g., during transmission using ultrashort waves. However, if transmission conditions get worse – e.g., when using short waves – it might be reasonable to decrease $N_1$ and $k$ in order to decrease transmission error probability. Good values in this case are $N_1 = 64$, $k = 1$ [2].

The results obtained clearly show that the buffer capacity strongly depends on relation between $V_w$ and $V_r$. Indeed, when $V_w$ exceeds $V_r$ only slightly, buffer capacity required to ensure continuous transmission on sender side is relatively small when compared to $L_D$. On the other hand, when $V_r$ is much smaller than $V_w$, buffer capacity is comparable to $L_D$. This observation concerns both half-duplex and full-duplex cases.

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Tab. 1. Example calculation results for half-duplex radio link

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Tab. 2. Example calculation results for full-duplex radio link
"Speed-up" time ($T_{SpUp}$) depends on both wired and wireless link transmission rate, not effective throughput. Thus, results for half-duplex and full-duplex link are identical. When transmission rates are at least as high as 9.6 kbps, speed-up time is no larger than half a second and decreases down to 10 ms for the highest considered rates. Therefore, in many cases it is negligible. In turn, "slow-down" time ($T_{SlDn}$) is in many cases almost as long as $T_p$. It results from the duration of wireless transmission ($T_p$) and occurs especially when effective throughput of wired link significantly exceeds that of wireless link and most of the transmitted data must be placed in a buffer. Finally, $T_a$ depends on wired link transmission rate only. As it can easily reach high values, $T_a$ falls down to few milliseconds. Hence, it does not play an important role in total transmission time, provided that $T_p$ is sufficiently long. It occurs when $L_D$ is large enough, or when effective throughput of the wireless link ($V_{wl}$) is low. As a result, effective throughput between computers ($V_{ef}$) is not much lower than $V_{wl}$ that occurs between TNC controllers.

Results for full-duplex link are more optimistic than for half-duplex one. Transmission times are shorter and effective throughput of a wireless link is higher. Thus, it should not be surprising that buffer capacity for full-duplex link is substantially lower than for half-duplex one.

The presented results show that – as expected – AX.25 link is a bottleneck of the presented network configuration. It is caused not only by low transmission rate of a radio link, but also by protocol operation and accepted parameters. What seems surprising, buffer capacity that ensures continuous transmission on sender side, is about 80÷95% of entire information size. Thus, for large sizes of the information, continuous transmission should not be expected.

Calculated times and transmission speeds are very close to the results of measurements obtained in an experimental Packet Radio network using Symek TNC3 [6] and NT-G TNC7multi [3] controllers. Buffer capacity, however, can’t be compared so easily, because even during transmission of 8 KB file transmission pauses on RS-232 link have been observed. It doesn’t mean that the buffer has lower capacity – transmission pausing may occur long before possible buffer overflow, in case the application running on attached computer does not stop sending characters immediately.

5. Conclusions

In this paper basic properties of TNC controllers and AX.25 protocol used in Packet Radio network have been briefly described. On the basis of this characteristics an analytical model has been developed. It describes operation of TNC controller and influence of individual transmission parameters upon network efficiency. Presented model allows estimate not only effective transmission speed that can be obtained in a network using TNC controllers – in contrast to [10], where AX.25 protocol was considered itself – but
also delays of transmission start and end on the receiver side. Besides presented model allows estimate minimum buffer capacity required to ensure continuous transmission on sender side. It is essential as – because of much lower effective transmission speed of radio link compared to wired on – in case of small buffer transmission may be paused from time to time in order to prevent overflow and, what follows, partial information loss.

Developed model shows sufficient accuracy and gives results similar to experimental ones, obtained with real TNC controllers. Thus, it can serve as a reference point that allows estimate influence of construction parameters upon selected usable network parameters.

It must be noticed, however, that similarity of the results strongly depends on the type of TNC controller and its control software. Under such circumstances, the calculated numbers may be used as a reference point for results achieved by measurements in an experimental Packet Radio network. For example, it can be used to determine if a particular TNC controller has enough processing power to efficiently use radio link operating at a given transmission rate, or if its control software has been sufficiently optimised.

On the basis of the presented model, a simulation model could be developed. It would allow achieve results in more complex networks, under more realistic conditions – not excluding interference, collisions etc. Such results would be very useful during design of any TNC-based network.

References

Model analityczny kontrolera TNC

Streszczenie

Kontrolery TNC są układami mikroprocesorowymi, służącymi do przesyłu informacji w sieci Packet Radio. Sieć ta może być rozważana jako przykład bezprzewodowej sieci rozległej.

W niniejszym artykule przedstawiono analityczny model pracy kontrolera TNC, uwzględniający podstawowe zależności, wynikające z właściwości protokołu transmisyjnego stosowanego w sieci Packet Radio oraz zasad pracy kontrolera. Model ten uwzględnia działanie sieci w warunkach idealnych, w najprostszej konfiguracji, zawierającej dwie stacje z kontrolerami TNC.

Przy pomocy modelu można wyznaczyć efektywną prędkość transmisji łącza bezprzewodowego (między kontrolerami) oraz przewodowego (między kontrolerem a dołączonym do niego komputerem), a także efektywną prędkość transmisji między komputerami z uwzględnieniem obecności kontrolerów. Model pozwala także oszacować opóźnienia rozpoczęcia i zakończenia transmisji, tj. czas, jaki mija między rozpoczęciem lub zakończeniem transmisji na wejściu i wyjściu kontrolera. Ponadto, za pomocą modelu można oszacować pojemność bufora danych w kontrolerze, zapewniającą ciągłość transmisji w łącze przewodowym pomimo jego większej (w większości przypadków) efektywnej prędkości transmisji. Za pomocą wyprowadzonych zależności analitycznych uzyskane zostały wyniki numeryczne dla kilku typowych przypadków sieci Packet Radio. Wyniki obliczeń zebrano w tabelach 1 i 2.

Model może posłużyć jako punkt odniesienia przy porównywaniu praktycznych osiągów kontrolerów TNC różnych typów, w szczególności przy określaniu czynników, mających wpływ na ich wydajność. Może także być pomocny przy szacowaniu prędkości czy opóźnień transmisji, co może być istotne w zastosowaniach wymagających determinizmu czasowego sieci.