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# Enhanced call processing discipline for control and charging in 4G network

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**Abstract**

The tendency of charging development and policy call processing management systems is to deploy the convergent architecture call processing and charging [1]. Those systems can increase the flexibility of charging mechanism which becomes the way of impact on call processing policy. This approach gives opportunity to create call policy processing with different parameters: quality of service, service priority, subscriber priority, etc. The article focused on current disciplines of serving calls in PCC subsystems of 4G systems, which affects the charging procedure and may increase the profit of carrier.

**Keywords**: serving discipline, 4G networks, policy control and charging, management system architectures, charging mechanism.

## Wzmocniony tryb przetwarzania połączeń do kontroli i taryfikacji w sieciach 4G

**Streszczenie**

Tendencją rozwoju systemów taryfikacji i zarządzania przetwarzaniem ruchu telekomunikacyjnego jest tworzenie zgodnej architektury systemów dla realizacji obu tych zadań. Takie systemy mogą zwiększać elastyczność mechanizmów taryfikacji, co stanowi ważny cel polityki przetwarzania ruchu telekomunikacyjnego. Jednolite podejście stwarza możliwość realizacji polityki przetwarzania ruchu telekomunikacyjnego przy wykorzystaniu różnych parametrów: jakości usług (QoS), priorytetów obsługi, priorytetu subskrybenta itp. Praca dotyczy aktualnych wymagań obsługi połączeń w podsystemach obsługi taryfikacji należących do systemów 4G, co może prowadzić do zwiększenia zysku dostawcy. Zaproponowano oryginalny tryb serwisu przy przetwarzaniu informacji multimedialnych w sieci bezprzewodowej z dostępem OFDMA. Wykorzystano model oparty na rozkładzie Poissona. Uwzględniona została szerokość pasma wymaganego przez usługę przy przeciążeniu sieci. Zaproponowany tryb pozwala lepiej wykorzystać połączenia i nie zmniejsza ilości usług w sieci. Badania eksperymentalne pokazały, że tryb ten jest wydajniejszy od innych., stosowanych dotychczas.

**Słowa kluczowe**: dyscyplina usług, sieci 4G, polityka kontroli i taryfikacji, architektury systemów zarządzania, mechanizm taryfikacji.

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## 1. Introduction

Policy control charging architecture, PCC [1], is developed by ETSI, 3GPP, 3GPP2 and is compatible with networks UMTS, LTE [2]. The concept depends on managing of user charging and tarification policy as well as call processing independently from network access. However the charging mechanism has to consider network specific parameters such as QoS, bit rate, network resource, etc.

Future 4G networks mostly correspond to demands of multimedia services, Tab. 1.

Tab. 1. Comparison of technical parameters of wireless network
Tab. 1. Porównanie parametrów technicznych sieci bezprzewodowych

| Technical parameters | GSM | 3 UMTS | 4G/LTE |
|---|---|---|---|
| Capacity | Up to 384 kbit/s | 384 kbit/s – 2 Mbit/s | 100 Mbit/s – mobile mode, 1 Gbit/s – stationary mode |
| Switching technology | Channel | Channel and packet | Packet |
| “End-to-end” QoS provisioning | No | Partly | Full |
| Security for packet traffic | Generally not support | Generally not support | Support |
| Multicast | Not support | Not support | Support |
| Charging packet service with QoS | Not support | Not support | Support |
| MIMO | Not support | Not support | Support |
| Access technology | TDMA | WCDMA | OFDMA |

The charging mechanism in 4G networks takes into account such parameter as QoS, bit rate of subservice, priority, etc. [7, 8]. However detail analysis of charging process shows that one of basic parameter – frequency band per service, that is the main resource element has not been considered [2].

## 1.1. Model call processing in 4G networks

The model of call processing in 4G networks is shown in Fig. 1.

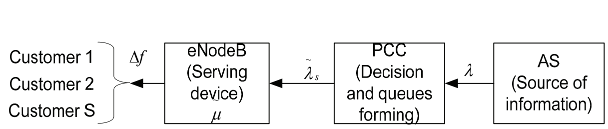


Fig. 1. The model of call processing in 4G networks
Rys. 1. Model przetwarzania ruchu telekomunikacyjnego w sieciach 4G

Model description:

Application server (AS) plays role of information source, that generates calls with $\lambda$ intensity. It comes to decision block– policy and charging rules function (PCRF), which is the part of PCC architecture [2]. PCRF forms queues for call processing after checking the Node B resource ability, and according to service discipline sends them to the eNodeB. ENodeB fulfills the channel set function serving the calls.

Queuing discipline is formed by PCRF defining conditions when call service processing stops, how we choose call from queue for process, and what have to be done with partly served call. There are different services disciplines: FIFO, LIFO, Random, Priority, etc. [4].

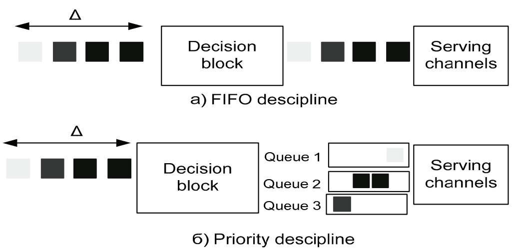


Fig. 2. The working principle of disciplines
Rys. 2. Zasady kolejkowania

The disciplines implementation gives opportunity to operator to increase the efficiency of the network serving, for example, the customer service based on SLA or call process based on service priority. Such disciplines are realized in new mobile switching centers with soft switching architecture NGN, IMS [3, 5].

In the paper, authors propose to use new discipline based on priority which defines the ratio of online service tariff to bandwidth used for it's provisioning in mobile network, based on OFDMA access technology.

## 1.2. Improving the queuing discipline in PCC architecture

The mobile system characteristics are stated below:

1) Assume, that mobile network (Fig. 1) consists of one Base Station, eNodeB, block of call and charging management, which defines the service discipline, application server (AS) and customers.
2) AS generates calls with intensity $\lambda$ which corresponds to Poisson distribution, and comply with stationary flow principles [6]. There is suggested additional characteristic for each call represented by coefficient $w_k = \frac{Tr_k}{\Delta f_k}$, where $Tr_k$ denotes the service rate per time unite, and $\Delta f_k$ - bandwidth needed for service provisioning.
3) Assume, that during the session the bandwidth value appointed to service is constant.

**Hypothesis:** the average profit from serving calls can be increased comparing with FIFO, Priority based on service QoS, if PCC serves calls which comply two conditions:

1) - $\max\{w_1, w_2,.., w_l,..w_k\}$,
2) if $w_k \geq w_l$, then $Q_k \geq Q_l$, where $Q_i$ denotes the quality level of call. It's claimed that dropped calls number of resource shortage would not be increased.

## 2. Formulation working principle of RF service discipline

1. If during the period [0; *t*], comes $N(t) > 0$ calls, and channel is free, than *j* call is served firstly under condition that $w_j \geq w_i$, where $i = 0...N(t)$. Others calls are dropped.
2. If during the period [0; *t*], comes $N(t) > 0$ and channel is busy than calls drops.
3. If during the period [0; *t*], comes $N(t) = 0$, system waits [0; *t*] period, then refer to 1.

To prove the hypothesis the analytic expression of profit mathematical expectation values have to be found for FIFO, Priority and RF discipline. There is proposed to solve the task for next cases:

1) M/M/1 model. One type call has fixed capacity and fixed price**.**
2) M/M/N model (version 1). One type of call has fixed capacity and different price.
3) M/M/N model (version 2). One type of call may require different capacity and has different rates. To simplify mathematical calculation we consider only case when calls may require different rates and the same capacity. This is subcase of general case.

### 2.1. M/M/1 model

Assume that call flow comply with Poisson flow with intensity $\lambda$, and $N(t)$ denotes the quantity of calls coming during 0 to *t* period, $N(t)$ is Poisson process [6]. The probability that during 0…*t* period the coming number calls equals *m* is expressed by [6]:

$$P(N(t) = m) = \frac{(\lambda \cdot t)^m}{m!} e^{-\lambda \cdot t} \tag{2.1}$$

where $m = 0,1,2...$ - coming calls; $t \geq 0$ - time condition; $\lambda$ - call coming intensity.

The probability that there will be no calls coming during 0…*t* period is expressed by:

$$P(N(t) = 0) = e^{-\lambda \cdot t} \tag{2.2}$$

Thus the probability that there will be more than 1 call coming during 0…*t* equals:

$$P(N(t) \neq 0) = 1 - P(N(0;t) = 0) = 1 - e^{-\lambda \cdot t} \tag{2.3}$$

The working principle of the FIFO discipline is shown in Fig.3. There is only one serving channel.

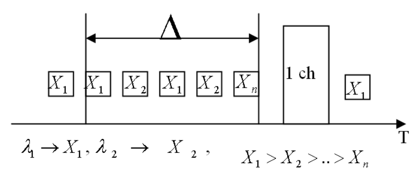


Fig. 3. PCC with discipline FIFO M/M/1
Rys. 3. Kolejkowanie FIFO w modelu M/M/1

Assume that $X_i$ is the profit from call with intensity $\lambda_i$. Then the profit is equal to mathematical expectation for FIFO models. It equals to product of probability $P(t, N \geq 1, i)$ and profit from call $X_i$:

$$M_{fifo}[X] = \sum_{i=1}^{m} X_i \cdot P(t, N \geq 1, i) \tag{2.4}$$

where $M_{fifo}[X]$ - profit mathematical expectation for FIFO; *m* - quantity of calls type; $X_i$- rate of *i*- type call; $P(t, N \geq 1, i)$ - probability that during period 0…*t,* it would come more than 1 call, and among them will be *i*-type call. Probability $P(t, N \geq 1, i)$ can be calculated:

$$P(t,N\geq 1,i)=P(t,N\geq 1)\cdot P(t,i) \qquad (2.5)$$

where $P(t,N\geq 1)$ - probability, that during period $0\ldots t$ would come more than 1 call, $P(t,i)$ - probability that $i$-type call comes during period $0\ldots t$.

Probability $P(t,N\geq 1)$ equals to the difference between all possible events, which have probability equals 1 and probability meaning that will be no incoming calls, equation (2.6). The equation (2.7) gives probability $P(t,i)$.

$$P(t,N\geq 1)=1-e^{-\sum_{i=1}^{m}\lambda_i t} \qquad (2.6)$$

$$P(t,i)=\frac{\lambda_i}{\sum_{k=1}^{m}\lambda_i} \qquad (2.7)$$

where $\lambda_i$ - intensity of $i$ type calls, $i=1\ldots m$, $m$- quantity of call types.

Taking into account expressions (2.6) and (2.7), profit mathematical expectation can be obtained:

$$M_{fifo}[X]=\sum_{i=1}^{n}X_i\cdot(1-e^{-\sum_k^n \lambda_k t})\cdot\frac{\lambda_i}{\lambda} \qquad (2.8)$$

In Fig.4 the working mechanism for RF discipline is shown.

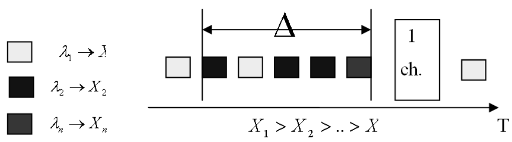


Fig. 4. PCC with discipline RF, M/M/1
Rys. 4. Kolejkowanie RF w modelu M/M/1

The profit mathematical expectation $M_{RF}[X]$ for RF service discipline calculated like sum multiplication of rate $X_i$ to probability that there will be no call with high priority than $i$.

$$M_{RF}[X]=\sum_{i=1}^{N}X_i\cdot P(t,m\geq 1)\cdot P(t,N(t)\neq(i+1),(i+2),..(i+n) \qquad (2.9)$$

where $M_{RF}[X]$ - the profit mathematical expectation for RF discipline; $P(t,N(t)\neq(i+1),(i+2),..(i+n)$ - probability that more than 1 high priority call would not come.

Let $P(t,N(t)\neq(i+1),(i+2),..(i+n)$ equals $P^*(t)$ to simplify the formulary record. Than taking into account (2.3) $P^*(t)$ expression can be presented:

$$P^*(t)=e^{-t\cdot(\lambda_{i+1}+\lambda_{i+2}\ldots\lambda_{i+n})} \qquad (2.10)$$

The profit mathematical expectation $M_{RF}[X]$ can be written:

$$M_{RF}[X]=\sum_i X_i\cdot(1-e^{-\lambda_i t})\cdot e^{-t\cdot(\lambda_{i+1}+\lambda_{i+2}\ldots\lambda_{i+n})} \qquad (2.11)$$

Thus the calculation of profit mathematical expectation for RF and FIFO models will be got. The model RF discipline condition is equivalent to priority service discipline.

## 2.2. M/M/N model – version1

The case regarded is one call type, fixed capacity and different price The profit mathematical expectation $M[X]$ for model M/M/N should take into account quantity of channels, thus the following expression has been obtained:

$$M_{FIFO}[X_1+X_2+,\ldots+X_n]=\sum_{k=1}^{n}P_k(t)\cdot M[X_k] \qquad (2.12)$$

where $M[X_k]$ - the profit mathematical expectation of call with $X_k$, which comes for period $\Delta$; $P_k(t)$ - probability of $k$ channel, which will be released for period $\Delta$.

The probability $P_k(t)$ can be finding as the solution of Kolmogorov system equations:

$$P_k(t)=\frac{(n\cdot\mu\cdot\Delta)^k}{k!}e^{-n\cdot\mu\cdot\Delta} \qquad (2.13)$$

where $\mu$ - intensity of serving calls; $\Delta$ - period of $k$ time channels released, $k=1\ldots n$, $n$ - maximum quantity of channels in system.

Taking into account (2.13) and (2.12), the profit mathematical expectation for calls with FIFO service discipline equals

$$M_{FIFO}[X_1+X_2+,\ldots+X_n]=\sum_{j=o}^{n}[X_j\cdot\frac{\lambda_j}{\lambda}]\cdot\sum_{k=1}^{n}P_k\cdot[1-\sum_{i=0}^{k-1}\frac{(\lambda\cdot\Delta)^i}{i!}\cdot e^{-\lambda\cdot\Delta}] \qquad (2.14)$$

In similar way the profit mathematical expectation for calls with RF discipline can be obtained:

$$M[X_k]=\sum_{k=1}^{n}P_k\sum_{i=1}^{k}X_i\sum_{j=0}^{k}(\frac{((\lambda_1+..+\lambda_{i-1}))\cdot\Delta)^j}{j!}\cdot e^{-(\lambda_1+..+\lambda_{i-1})\cdot\Delta}\cdot(1-\sum_{l=0}^{k-j-1}\frac{(\lambda_i\cdot\Delta)^l}{l!}\cdot e^{-\lambda_i\cdot\Delta}) \qquad (2.15)$$

Thus, the calculation of the profit mathematical expectation for RF and FIFO models M/M/N has been obtained. According obtained results it is possible to see that the conditions of the RF discipline model are equivalent to priority service discipline.

## 2.3. M/M/N model – version 2

The case regarded is one call type with equal capacity and different price. Assume that the profit mathematical expectation $M[X_j^{(n)}]$ for RF discipline with M/M/N, from $k$ call types, $k+1,..,n$, under the condition that $j$ cells are free, where $j=\overrightarrow{0...N}$, $N$ - maximum quantity of cells which can be released for time period $\Delta$.

$$M[X_j^{(n)}]=\sum_{i=0}^{\left[\frac{j}{c_n}\right]}i\cdot c_i\cdot\omega_i\cdot P_i^{(n)} \qquad (2.16)$$

where

$$P_i^{(n)}=\begin{cases} e^{-\lambda_n\cdot\Delta}\cdot\frac{(\lambda_n\cdot\Delta)^i}{i!}, i<\left[\frac{j}{c_n}\right] \\ 1-\sum_{i=0}^{\left[\frac{j}{c_n}\right]-1}e^{-\lambda_n\cdot\Delta}\cdot\frac{(\lambda_n\cdot\Delta)^i}{i!}, i=\left[\frac{j}{c_n}\right]\end{cases} \qquad (2.20)$$

where $P_i^{(n)}$ - probability of serving $n$ call type under condition that $P_i^{(n)}$ is probability for free cells; $c_n$ - quantity of cells that require $n$ call type for processing; $j$- quantity of free cells; $\omega_i$ - ratio of rate to bandwidth consumed by service $c_i$.

In this case, the profit mathematical expectation for RF discipline can be found using the expression:

$$M[X_j^{(k)}] = \sum_{i=0}^{\left[\frac{j}{c_k}\right]} P_i^{(n)} \cdot (i \cdot c_k \cdot \omega_k + M[X_j^{(k+1)}] \cdot (j - c_k \cdot i)) \quad (2.21)$$

## 3. The modeling results

The graphs of the profit mathematical expectation for serving calls in dependence with waiting time and the quantity of cells that require for processing for FIFO, Priority and RF disciplines are shown in Fig. 5.

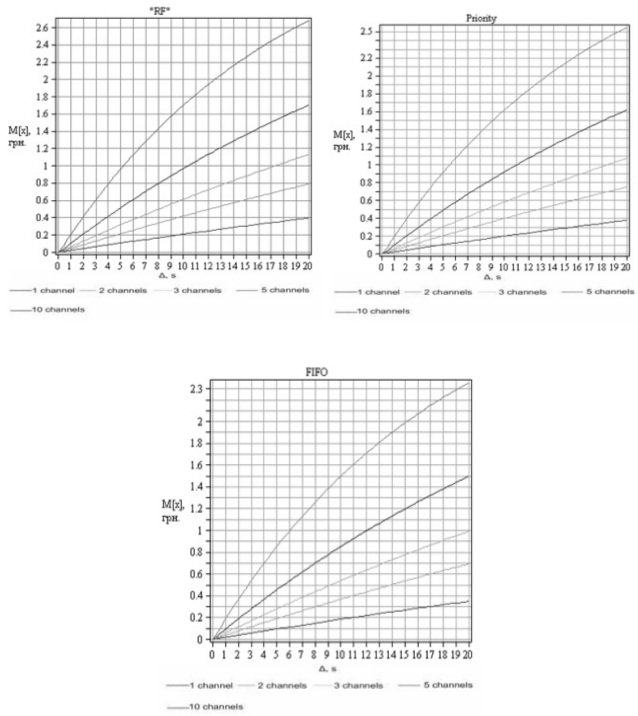


Fig. 5. Curves of the profit mathematical expectation for serving calls in dependence of waiting time and the quantity of cells for FIFO, Priority and RF disciplines

Rys. 5. Krzywe wartości oczekiwanej dla obsługi ruchu telekomunikacyjnego w zależności od czasu oczekiwania i ilości komórek FIFO, priorytetu i reżimu RF

According the modeling results (Fig. 5) it's possible to get the conclusion that when the quantity of cells is increased it is possible to serve more calls and to get more profit.

The efficiency relative comparison of the profit mathematical expectation for serving calls with FIFO, Priority and RF disciplines is shown in Fig. 6.

The modeling results (Fig. 6) show the following:

- the suggested discipline RF gives the best effect in comparison with discipline FIFO and Priority in 13% and 5.4% respectively, when serving with waiting time 5 s;
- the growth velocity of effect decreases when the waiting time increases;
- the profit is strongly depended of the call coming intensity and theirs average serving time.

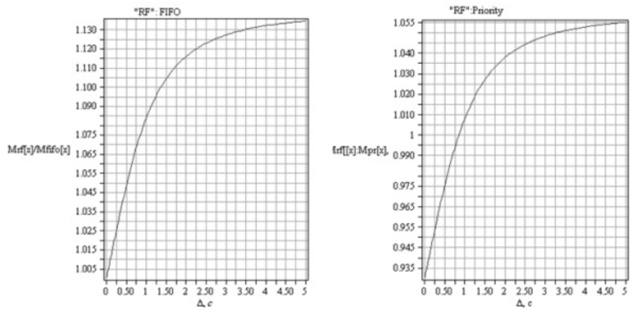


Fig. 6. The efficiency relative comparison of the profit mathematical expectation for serving calls with FIFO, Priority and RF disciplines

Rys. 6. Porównanie osiągów wyrażonych wartością oczekiwaną przy obsłudze ruchu telekomunikacyjnego, przy zastosowaniu reżimów FIFO, Priorytetu i RF

## 4. Conclusions

1. The original service discipline is proposed for processing multimedia service in mobile network with OFDMA access. The discipline takes into account bandwidth capacity required by the service for provisioning during the network overload.
2. Proposed service discipline allows increasing the operator profit serving more profitable calls, and doesn't decreases the quantity of serves call in the network.
3. Experimental investigation shows that discipline is more efficient of 13.5% and 5.5% than FIFO and Priority, respectively. This feature can be especially useful when serving "long" multimedia services which occupy large bandwidth with high occurrence which are typical for current telecommunication service.

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