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VA YECHIMLAR**

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Annotatsiya

Mazkur to'plamda "Yangi davr ilm-fani: inson uchun innovatsion g'oya va yechimlar" mavzusidagi XIX Respublika ilmiy-amaliy konferensiyasi materiallari jamlangan. Nashrda respublikaning turli oliy ta'lim muassasalari, ilmiy markazlari va amaliyotchi mutaxassislari tomonidan tayyorlangan maqolalar o'rin olgan bo'lib, ular ijtimoiy-gumanitar, tabiiy, texnik va yuridik fanlarning dolzarb muammolari va ularning innovatsion yechimlariga bag'ishlangan.

Ushbu nashr ilmiy izlanuvchilar, oliy ta'lim o'qituvchilari, doktorantlar va soha mutaxassislari uchun foydali qo'llanma bo'lib xizmat qiladi.

Kalit so'zlar: ilmiy-amaliy konferensiya, innovatsion yondashuv, zamonaviy fan, fanlararo integratsiya, ilmiy-tadqiqot, nazariya va amaliyot, ilmiy hamkorlik.

Barcha huquqlar himoyalangan.

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TEXNIKA FANLARI

5G NR SLICE'LARI TRAFIGINI TAVSIFLASH UCHUN EHTIMOLIY TAQSIMOTLARNI TANLASHNING QIYOSIY TAHLILI

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Annotatsiya. 5G NR tarmoqlarida eMBB, URLLC va mMTC slice'lari o'rtasida radiokanal o'tkazish polosasini taqsimlash natijasi trafikning statistik modeliga bevosita bog'liq. Mavjud modellarda trafik ko'pincha Puasson yoki real o'lchovlarga to'liq mos kelmaydigan taqsimotlar bilan ifodalanadi. Tezida bitta uzatish intervalida (TTI) keladigan paketlar sonini tavsiflovchi ehtimoliy taqsimotlarni tanlash masalasi 17 ta ilmiy manba asosida qiyosiy tahlil qilindi. Sharhlarda keltirilgan standart modellar, real tarmoq o'lchovlari va nazariy natijalar qiyoslanib, har bir slice uchun nomzod taqsimot hamda G/G/1 navbat modeliga kiritiladigan variatsiya koeffitsientining analitik ifodasi keltirildi. eMBB uchun kesilgan Pareto, URLLC uchun siyrak yuklama rejimidagi Bernulli approksimatsiyasi, mMTC uchun esa murakkab Puasson taqsimotlari asoslandi va ularning o'tkazish polosasiga ta'siri baholandi. Pareto va Hurst parametri o'rtasidagi bog'lanishning evristik xususiyati, natijaning kesish chegarasiga sezgirligi, murakkab Puasson jarayoni o'z-o'ziga o'xshashlikni emas, balki portlashlilikni ifodalashi hamda ikki momentli approksimatsiya uzoq muddatli bog'liqlikni hisobga olmasligi ko'rsatildi. Olingan ifodalar sun'iy intellekt asosidagi neyron tarmoq approksimatori uchun o'quv ma'lumotlarini shakllantirishda qo'llanilishi mumkin.

Kalit so'zlar: trafik modeli, kesilgan Pareto, Bernulli, murakkab Puasson, Hurst parametri, variatsiya koeffitsienti, G/G/1, network slicing.

COMPARATIVE ANALYSIS OF PROBABILITY DISTRIBUTION SELECTION FOR DESCRIBING 5G NR SLICE TRAFFIC

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Annotation. In 5G NR, distributing radio channel bandwidth among eMBB, URLLC and mMTC slices depends on the statistical model of traffic. This paper presents a comparative analysis of 17 sources on selecting distributions describing the number of packets arriving within one transmission time interval (TTI). Standard models, real network measurements and theoretical results are compared, and for each slice a candidate distribution and an analytical expression of the coefficient of variation used in the G/G/1 queueing model are given. A truncated Pareto distribution is substantiated for eMBB, a Bernoulli approximation in the sparse-load regime for URLLC, and a compound Poisson distribution for mMTC. It is shown that the Pareto-Hurst relation is heuristic, results are sensitive to the truncation bound, the compound Poisson process represents burstiness rather than self-similarity, and the two-moment approximation ignores long-range dependence. The obtained expressions can be used to generate training data for an AI-based neural network approximator.

Keywords: traffic model, truncated Pareto, Bernoulli, compound Poisson, Hurst parameter, coefficient of variation, G/G/1, network slicing.

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Kirish

Chen va Zhao [8] ga ko'ra, 5G trafigi asosan bino ichi va hotspot zonalarida to'planadi, DL/UL nisbati 10:1 gacha o'sadi, shu sababli taqsimlash natijasi trafik modeliga kuchli bog'liq. AlQahtani [2] ning CTMC modelida so'rovlar Puasson oqimida keladi va xizmat vaqti eksponensial, Amirsaidov va Qodirov [3] da esa $M/M/1/L$ navbat modeli qo'llanadi; bunday farazlar portlashlilikni aks ettirmaydi. Amirsaidov va Turumbetov [4] bu cheklovni $G/G/1$ modeli va Weibull, binomial, normal taqsimotlar orqali qisman bartaraf etgan. Ishning maqsadi — [4] dagi taqsimotlarni qiyosiy baholab, har bir slice uchun asoslangan nomzod taqsimotni aniqlash; bu sun'iy intellekt (neyron tarmoq) asosidagi taqsimlash modeli uchun o'quv ma'lumotlarini shakllantirishga xizmat qiladi.

Metodlar va uslublar

17 ta manba qiyosiy tahlil qilindi; baholash apparati sifatida [4] dagi Kingman tipidagi approksimatsiya [17] olindi:

$$t = \frac{\rho t_s}{1 - \rho} \cdot \frac{C_\lambda^2 + C_\mu^2}{2} + t_s, \quad (1)$$

bu yerda t_s — o'rtacha xizmat vaqti, ρ — yuklama, $C_\lambda = \frac{\sqrt{V}}{M}$ — bitta TTI dagi paketlar soni (o'rtachasi M , dispersiyasi V) ning variatsiya koeffitsienti, C_μ — xizmat vaqtining variatsiya koeffitsienti. Trafik (1) ga faqat C_λ orqali kiradi, shuning uchun nomzod taqsimotlar manbalar bilan mosligi va C_λ^2 ning analitik ifodasi bo'yicha baholandi. C_λ ni 1 dan 3 gacha oshirish kutish komponentini $C_\mu = 1$ da 5 marta, $C_\mu = 0$ da 9 marta oshiradi. (1) faqat ikkinchi momentga tayanadi va uzoq muddatli bog'liqlikni aks ettirmaydi.

Tadqiqot natijalari

eMBB. Becchi [7] ga ko'ra, ma'lumotlar trafigi uzoq muddatli bog'liqlik ($H > 0,5$) va og'ir dumli taqsimotlar bilan tavsiflanadi, Mitzenmacher [11] fayl hajmlari uchun «qo'sh Pareto»ni asoslaydi. 3GPP [12] video paketlar uchun kesilgan Pareto ($\alpha = 1,2$), Soos va b. [15] real 5G da katta paketlar va UL/DL asimmetriyani qayd etadi. [4] da Weibull $B = 2 - 2H$ bilan qo'llanadi:

$$C_\lambda^2 = \frac{\Gamma(1 + 2/B)}{\Gamma^2(1 + 1/B)} - 1; \quad (2)$$

$H = 0,8$ da $C_\lambda \approx 3,14$ va polosa 3 barobar ortadi [4]. Taqqu va b. [16] Pareto davrli ON/OFF manbalar uchun $H = (3 - \alpha)/2$ ($1 < \alpha < 2$) ni isbotlagan; uni TTI ga ko'chirish evristikdir, $\alpha \geq 2$ da esa qo'llanmaydi. $\alpha < 2$ da dispersiya cheksiz, shuning uchun $k \leq x \leq m$ oraliqdagi kesilgan Pareto qo'llaniladi:

$$E[X^n] = \frac{\alpha k^\alpha (m^{n-\alpha} - k^{n-\alpha})}{(n - \alpha)(1 - (k/m)^\alpha)}, \quad C_\lambda^2 = \frac{E[X^2]}{E^2[X]} - 1. \quad (3)$$

$\alpha = 1,4$ da $m/k = 10; 100; 1000$ uchun $C_\lambda \approx 0,71; 1,73; 3,53$: natija kesish chegarasiga kuchli bog'liq, u o'lchovlar yoki sezgirlik tahlili bilan tanlanishi lozim.

URLLC. Trafik 1 ms va $1-10^{-5}$ ishonchlilik talabli 32 baytli siyrak paketlar [4], [9], [12]; [6], [10] da kelish Puasson, [5] da mini-slot talabi ikki qiymatli, [4] da esa binomial (N, P) . Agregat «paket bor/yo'q» Bernulli approksimatsiyasi va binomial uchun:

$$C_\lambda^2 = \frac{1-p}{p}, \quad C_{\lambda, bin}^2 = \frac{1-P}{NP}, \quad C_{\lambda, bin}^2 - C_\lambda^2 = \frac{N-1}{N}, \quad (4)$$

bu yerda $p = NP$. Bernulli approksimatsiyasi bir TTI da ikki va undan ortiq paket kelishini e'tiborsiz qoldiradi, shuning uchun siyrak yuklamada ($p \ll 1$) o'rinli; p ortgan sari xato oshadi. Manbalar geterogenligi va korrelyatsiyasini hisobga olish keyingi yo'nalishdir.

mMTC. Ruiz-Guirola va b. [14] davriy (kvazi-davriy, xato < 7%) va hodisaviy (Puasson, xato < 11%) rejimlarni ajratadi; Navarro-Ortiz va b. [12] sharhidagi 3GPP TR 37.868 modeli guruhli sinxron kirishlarni ko'zda tutadi, talablar [1], [13] da berilgan. [4] dagi normal taqsimot simmetrik va guruhli kelishni aks ettirmaydi. Murakkab Puasson jarayoni [7] uchun (TTI dagi guruhlar o'rtachasi Λ , guruh hajmi B):

$$M = \Lambda \cdot E[B], \quad C_\lambda^2 = \frac{1 + C_B^2}{\Lambda}. \quad (5)$$

$\Lambda < 1 + C_B^2$ da $C_\lambda > 1$ (portlashli oqim); orttirmalar mustaqil bo'lgani uchun bu o'z-o'ziga o'xshashlik emas, ortiqcha dispersiya belgisidir (1-jadval).

1-jadval.

Slice'lar uchun trafik taqsimotlarining qiyosi

Slice	[4] dagi taqsimot	Manbalardagi xususiyat	Nomzod taqsimot va C_λ^2
eMBB	Weibull, $B = 2 - 2H$	Og'ir dum, uzoq muddatli bog'liqlik [7], [11], [12], [15]	Kesilgan Pareto (3); α — o'lchov yoki sezgirlik bo'yicha
URLLC	Binomial (N, P)	Siyrak diskret kelishlar [5], [6], [10]	Bernulli (siyrak rejim), (4): $C_\lambda^2 = (1-p)/p$
mMTC	Normal (μ, σ)	Davriy va hodisaviy, guruhli kirishlar [1], [12], [14]	Murakkab Puasson, (5): $C_\lambda^2 = \frac{1 + C_B^2}{\Lambda}$

Nomzod taqsimotlar [4] modeliga tuzilmani o'zgartirmasdan, faqat (M, V) juftligi orqali kiritiladi; natijalarni o'z-o'ziga o'xshash trafik bilan imitatsion modellashirishda tekshirish zarur.

Xulosa

Taqsimot tanlovi C_λ orqali polosa taqsimotini bevosita belgilaydi. Nomzod sifatida eMBB uchun kesilgan Pareto, URLLC uchun siyrak rejimdagi Bernulli approksimatsiyasi va mMTC uchun murakkab Puasson taqsimotlarini tekshirish maqsadga muvofiq; (3)–(5) ifodalar [4] dagi taqsimotlarni model tuzilmasini o'zgartirmasdan almashtirish imkonini beradi.

Hisoblangan optimal ulushlar (x_e, x_u, x_m) sun'iy intellekt (neyron tarmoq) approksimatori uchun o'quv ma'lumotlari bo'la oladi.

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